EXHIBIT 1

Dr. Stephen C. Danforth's Declaration in Support of Stratasys's Claim Construction Positions

UNITED STATES DISTRICT COURT
DISTRICT OF MINNESOTA

STRATASYS INC.,	)	
	)	
Plaintiff,	)	
	)	Civil No. 0:13-cv-03228 DWF-TNL
v.	)	
	)	
MICROBOARDS TECHNOLOGY, LLC d/b/a AFINIA,	)	
	)	
	)	
Defendant.	)	

DECLARATION OF STEPHEN C. DANFORTH, PH.D.

I, Stephen C. Danforth hereby declare as follows:

I. INTRODUCTION

1. I have been retained by plaintiff Stratasys Inc. ("Stratasys") as an expert witness to provide my opinions on several claim construction issues relating to the inventions claimed in U.S. Patent Nos. 5,866,058 (the "'058 patent"), 6,004,124 (the "'124 patent"), 8,349,239 (the "'239 patent") (collectively, the "patents-in-suit"). In particular, I have been asked to provide my opinion as to how a person of ordinary skill in the art would understand various claim terms from the '058, '124, and '239 patents. I have also been asked to provide a technical overview of the inventions in the patents-in-suit. In addition, I reserve the right to submit any declarations in rebuttal to any evidence (including expert testimony) submitted by Afinia.

II. QUALIFICATIONS AND COMPENSATION

2. Exhibit A is a copy of my current curriculum vitae ("CV").

3. I received my B.S. in Materials Science and Engineering in 1974, my M.S. in Materials Science and Engineering in 1975, and my Ph.D. in Materials Science and Engineering in 1978, all from Brown University.

4. I am currently a professor in the Department of Materials Engineering and Engineering, located in the Malcolm G. McLaren Center for Ceramic Research in the School of Engineering at Rutgers, The State University of New Jersey, and have held that position since 1994, and served as Chair of the Department of Ceramic and Materials Engineering from 2000 to 2006. Before becoming a professor, I was an associate professor from July 1987 to June 1994 and an assistant professor from August 1982 to June 1987 in the same department. I have also served as an adjunct professor in the Department of Mechanical Engineering at the University of Delaware since 1997. In addition, from May 1978 to July 1982, I was a research associate in the

Energy Laboratory in the Department of Materials Science at the Massachusetts Institute of Technology.

5. During my career, including during the 1990s and 2000s, I have researched and published extensively in the area of three-dimensional printing, and in particular, in the area of fused deposition of ceramics ("FDC"). FDC is a particular application of fused deposition modeling—a method of three-dimensional printing that involves building a prototype or model layer-by-layer from the bottom up by heating and extruding a thermoplastic material that solidifies upon cooling. One example of my research includes a project funded by DARPA that involved developing FDC technology and methods for potential applications in aerospace manufacture. Another example of my research includes a project funded by the Office of Naval Research and involved developing FDC technology for ultrasound transducers for DoD and for biomedical imaging applications. I have been invited to speak throughout the country and internationally on FDC, fused deposition modeling, and three-dimensional printing. I have also received honors and awards for my work in the field, including the "Highly Commended Award" and "Best Paper, Award for Excellence" for publications related to my three-dimensional printing work. I also regularly teach three-dimensional printing, including fused deposition modeling, in one of my undergraduate courses, and I have also taught graduate level courses on three-dimensional printing, including fused deposition modeling, in the past.

6. Examples of my publications are included in my CV.

7. In the last four years, I have not been deposed or testified at trial as an expert.

8. I am being compensated for my work in this case at a rate of $190/hour for non-testifying work and $250/hour for testifying work. My compensation is not in any way dependent on the outcome of the dispute.

III. MATERIALS REVIEWED

9. In forming my opinions set forth in this declaration I reviewed the ’058 patent, the prosecution history for the ’058 patent, the references cited by the ’058 patent, the ’124 patent, the prosecution history for the ’124 patent, the references cited by the ’124 patent (including U.S. Patent 5,340,433), the ’239 patent, the prosecution history for the ’239 patent, the references cited by the ’239 patent, Afinia’s List of Proposed Claim Terms to be Construed by the Court, Afinia’s Revised List of Proposed Claim Terms to be Construed by the Court, and Stratasys’s Preliminary Proposed Constructions and Identification of Extrinsic Evidence. Exhibit B is a complete list of all materials I have considered in connection with preparing this declaration.

IV. CLAIM CONSTRUCTION STANDARD

10. I understand that patent claim terms are to be interpreted in accordance with how a person of ordinary skill in the art would have understood the term as of the effective filing date of the patent application. In particular, I understand that claim terms should generally be given their ordinary and customary meaning, as understood by a person of ordinary skill in the art as of the patent’s effective filing date. I understand that the asserted patents in this case have the following effective filing dates: (1) the effective filing date of the ’058 patent is May 1997; (2) the effective filing date of the ’124 patent is January 1998; and (3) the effective filing date of the ’239 patent is September 2009. Accordingly, in forming my opinions on claim construction, I have considered (1) how a person of ordinary skill in the art would have understood the ’058 patent’s claims as of May 1997; (2) how a person of ordinary skill in the art would have understood the ’124 patent’s claims as of January 1998; and (3) how a person of ordinary skill in the art would have understood the ’239 patent’s claims as of September 2009.

11. In determining how a person of ordinary skill in the art would have understood a given term or phrase from a patent, I understand that it is important to look to the language of the claim and to the context of how the term or phrase is used in the claim. I also understand that it is important to consider the specification of the patent, including how the term or phrase is used in the context of the specification. I also understand that the prosecution history may provide guidance on the meaning of a term. I further understand that sources outside of the patent and its file history, such as dictionaries, treatises, or textbooks, may also provide evidence of how a person of ordinary skill in the art would have understood a particular term or phrase.

V. SUMMARY OF OPINIONS ON CLAIM CONSTRUCTION

12. I understand that the parties have agreed to the following claim interpretations.

For the ’058 patent:

- “creep relaxation temperature” means “temperature at which the stress relaxation modulus has dropped by a factor of 10 from its low temperature limit (indicating that it is sufficiently solid that modeling can occur)”
- “local region” means “the vicinity of the newly deposited material”

For the ‘124 patent:

- “exterior to the heating block” should have its plain and ordinary meaning

For the ‘239 patent:

- “oriented at a non-right angle” means “the orientation is at an angle that is not ninety degrees”

13. In my opinion, a person of ordinary skill in the art as of May 1997 would have understood the following terms in the ’058 patent to have the meanings set forth below:

- “solidification temperature” means “temperature at which a material behaves as a solid”

- “thermally solidifiable material” should have its plain and ordinary meaning; if it must be construed, it means “a material that can undergo a state change, from behaving as a fluid to behaving as a solid”

- “build region” should have its plain and ordinary meaning; if it must be construed, it means “volume of space in which an object can be built”

- “local region temperature” means “temperature in the vicinity of the newly deposited material”

- “cooling” should have its plain and ordinary meaning

14. In my opinion, a person of ordinary skill in the art as of January 1998 would have understood the following terms in the ’124 patent to have the meanings set forth below:

- “thin-wall tube” means “a single piece of tubing with wall thickness that allows the tubing to act as a cap zone and a heating zone”

15. In my opinion, a person of ordinary skill in the art as of September 2009 would have understood the following terms in the ’239 patent to have the meanings set forth below:

- “generating” should have its plain and ordinary meaning

- “interior region of a layer”/“interior region of the layer” should have its plain and ordinary meaning; if it must be construed, it means “an area defined by a perimeter of the layer”

- “start point” means “point where the contour tool path begins” in claim 1 and “point where the tool path begins” in claim 15

- “stop point” means “point where the contour tool path ends” in claim 1 and “point where the tool path ends” in claim 15

- “step-over arrangement” means “the intersection where the tool path steps from a perimeter to an interior or from an interior to a perimeter”

- “contour tool path” means “an extrusion head path that defines a perimeter of a layer of a three-dimensional object”

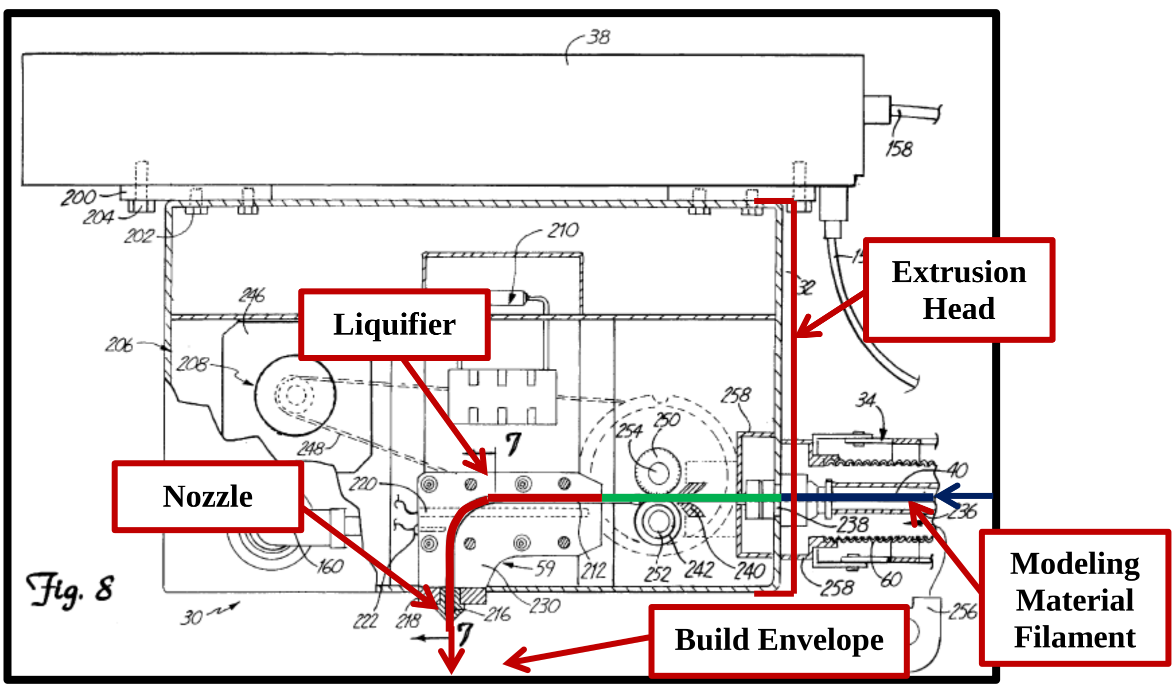
- “reduces surface porosity” means “reduces the transmission of gases and/or liquids through the seam”

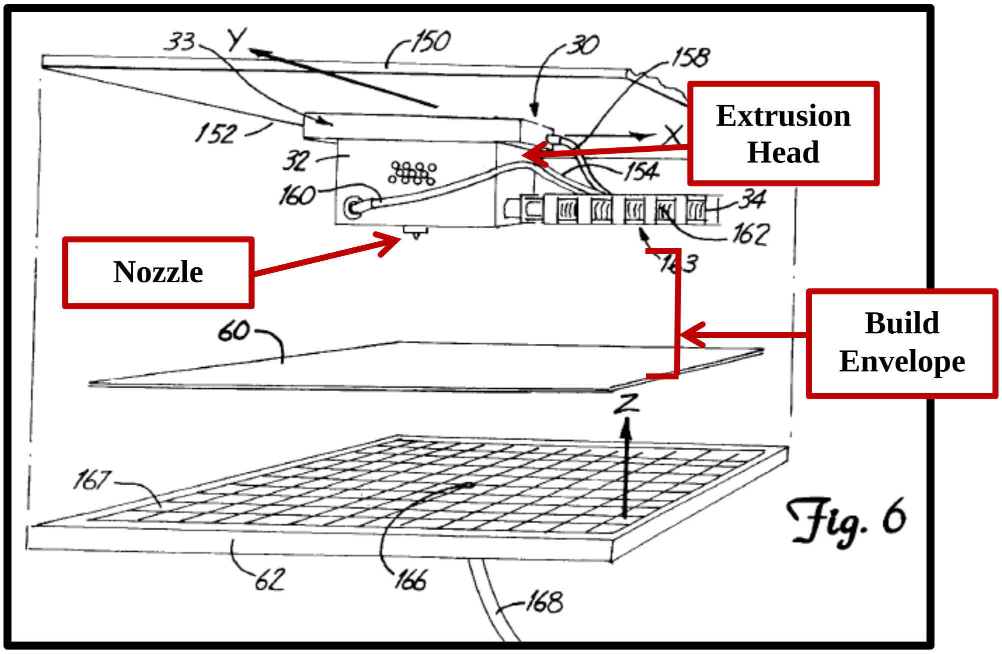
- “raster path” means “back and forth path”

- "tool path" means "path of the extrusion head for a layer of a three-dimensional object"
- "perimeter of a layer" should have its plain and ordinary meaning; if it must be construed, it means "road of modeling material that defines an interior region"

VI. OVERVIEW OF FUSED DEPOSITION MODELING

16. As I stated above, fused deposition modeling is a method of three-dimensional printing that involves building a prototype or model layer-by-layer from the bottom up by heating, melting, and extruding a thermoplastic material that solidifies upon cooling. Printers that utilize the fused deposition modeling method typically contain (1) modeling material in the form of a filament, (2) an extrusion head, (3) a liquifier, (4) a nozzle, and (5) a build envelope. Below I include annotated versions of Figure 8 and Figure 6 from the '124 patent to illustrate these printer components.





17. During printing, the printer feeds the modeling material filament into the extrusion head (labeled 32) using rollers (labeled 250 and 252) which are powered by a motor. Once inside the extrusion head, the modeling material is fed into the liquifier (labeled 59) where the material is heated to a flowable state (i.e., it behaves like a fluid). After the modeling material is heated to a flowable state, it is extruded out of a nozzle (labeled 216). The nozzle deposits the material layer-by-layer into a build envelope in the three-dimensional printing machine. The material is deposited in a predetermined pattern based upon design data provided from an accompanying software file, for example, a CAD file. Once deposited, the material solidifies upon cooling and adheres to the previous layer of material. As a result, a three-dimensional object is printed layer-by-layer, with each successive layer adhering to the one before it.

18. For clarity, in Figure 8 above, I also indicate the movement of the modeling material through the three-dimensional printer with different colors. The modeling material located outside the extrusion head is designated with navy blue, and the modeling material inside

the extrusion head but outside the liquifier is designated with green. The modeling material inside the liquifier and nozzle, where the material is in a flowable state, is designated with red.

VII. DETAILED OPINIONS ON CLAIM CONSTRUCTION ON THE ’058 PATENT

A. Person of Ordinary Skill in the Art

19. I understand that the person of ordinary skill in the art relating to an invention claimed in a patent is a fictitious person presumed to have the typical level of skill of practitioners in the field as of the effective filing date of the patent application, which I understand is May 29, 1997 for the ’058 patent. I understand that many factors are considered in defining a hypothetical person of ordinary skill in the art, including: (1) the types of problems encountered in the art; (2) the prior art solutions to those problems; (3) the rapidity with which innovations are made; (4) the sophistication of the technology; and (5) the educational level of active workers in the field.

20. In my opinion, the ’058 patent generally relates to three-dimensional printing and, in particular, fused deposition modeling. The ’058 patent, for example, states that the “invention relates to the rapid prototyping of solid models from thermoplastic materials.” ’058 patent, 1:5-6. This is a description of fused deposition modeling.

21. Based on my experience working in the field of fused deposition modeling in the 1990s, a person of ordinary skill in the art as of May 1997 typically would have had a B.S. degree in one of a number of possible scientific and/or engineering areas, including, for example, chemistry, physics, mechanical engineering, electrical engineering, materials science and engineering or industrial engineering. In addition, that person would also have had 1-3 years of experience working with fused deposition modeling. The graduate students and Rutgers faculty I

worked with on my FDC research and publications were skilled persons, as were others in the research and product development departments for companies with whom I worked in this field at that time. In my opinion, I possessed at least ordinary skill in the art as of May 1997.

B. Background of the Invention

22. The invention disclosed in the ’058 patent (attached as Exhibit C) relates to “the rapid prototyping of solid models from thermoplastic materials and, more particularly, to a method for rapid prototyping of models wherein curl and other modes of distortion are minimized.” ’058 patent at 1:5-8.

23. The ’058 patent discloses an improvement to a rapid prototyping (three-dimensional printing) system that generally involves creating a three-dimensional object by heating a thermally solidifiable material—for example, ABS plastic—in a liquifier and depositing sequential layers of the material in a flowable state onto a base. After each layer is deposited onto the base, the material solidifies, and the next layer is deposited on top of the previously deposited layer. In this fashion, the system builds up layers sequentially to form the desired three-dimensional object. *See id.* at 1:28-36. As I stated above, this disclosure describes a fused deposition modeling printer.

24. The ’058 patent describes a common problem with fused deposition modeling printers as of 1997. In particular, one significant problem with three-dimensional printing systems was that as deposited layers began to cool, the edges of the layers would start to “curl,” which would in turn deform the shape of the model. As described in the ’058 patent, fused deposition modeling systems “share[d] the challenge of minimizing geometric distortions of the product prototypes” that are produced when the material that is deposited on the base cools. *Id.* at 1:37-42. Particularly relevant here, the patent explains that the most frequent geometric

distortion encountered by three-dimensional printing systems is a "curl" distortion. *Id.* at 1:43-45. "Curl" is "a curvilinear geometric distortion which is induced into a prototype during a cooling period." *Id.* at 1:45-46. Specifically, the '058 patent describes that as the prototype cools, it distorts "as a result of a curling of the ends of long features." *Id.* at 2:6-10. For example, as a layer cools, the edges of the layer might distort by curling upwards, which over the course of time (and when present in multiple layers) could result in significant distortions to the shape of the printed model. It was this curl problem that the'058 patent specifically set out to solve.

25. The '058 patent discusses a number of prior art references that did not sufficiently address the issue of curl, including U.S. Patent Nos. 5,121,329, 4,749,347, and 5,141,680. The '058 patent specifically notes that "[w]hile the ['329 patent] incorporates a heated build environment, it requires that the deposited material be **below** its solidification temperature, as subsequent layers of material are added." *Id.* at 2:53-55 (emphasis added). Similarly, for the '347 and '680 patents, the '058 patent explains that "[b]oth patents teach a build environment that is maintained **at and below** the solidification temperature of the extrusion model." *Id.* at 2:59-61 (emphasis added). Thus, the '058 patent attributes the curl problems with the prior art—namely, U.S. Patent Nos. 5,121,329, 4,749,347, and 5,141,680—to the fact that the prior art used build environments with temperatures that were maintained **at or below** the solidification temperature of the modeling material. *Id.* at 2:49-61.

26. Unlike this prior art, which kept the build environment at or below the solidification temperature of the deposited material, the invention disclosed in the '058 patent sought to reduce curl by heating a region of the build environment such that it was **above** the solidification temperature of the deposited material. Claim 1, for example, requires a "build

region having at least a local region temperature that **exceeds the solidification temperature** of the thermally solidifiable material." *Id.* at 5:61-64. The specification likewise explains that maintaining the temperature in the local region above the solidification temperature has the advantage of reducing stress within the deposited material and thereby reducing curl: "[B]y maintaining a previously deposited material (in a rapid prototyping system utilizing thermal solidification) within a specific temperature window, th[e] stresses present in the deposited material are relieved and geometric distortions [are] reduced." *Id.* at 4:56-60. The patent teaches that at least "in the vicinity of where newly deposited material will be applied, the previously deposited material must be maintained at a temperature that is preferably in a range between the material's solidification temperature and its creep relaxation temperature." *Id.* at 4:60-65. Accordingly, the '058 patent overcame the geometric distortion problems in the prior art by maintaining the local region of the build environment above—i.e., "exceeds"—the solidification temperature of the thermally solidifiable material.

27. The '058 patent further recognizes that the solidification temperature and creep relaxation temperature vary based on the material being used. In particular, the patent explains that "there is a transition region between a material's fluid state and it's solid state" and where that temperature range lies depends on the type of material. *Id.* at 3:66-4:3. For glassy thermoplastics such as those disclosed for use with the invention of the '058 patent, the transition between the fluid state and the solid state is generally broader than for non-glassy materials. *Id.* at 4:3-5.

28. For example, the inventors of the '058 patent tested and accordingly defined this transition for the thermoplastic material ABS. *Id.* at 4:12-46. In particular, the inventors determined that ABS "has very little creep over 300 seconds, for temperatures up to about

70°C." *Id.* at 4:31-32. The inventors accordingly stated that 70°C "is therefore defined as the solidification temperature" for ABS. *Id.* at 4:32-33.

29. The '058 patent also refers to "creep relaxation temperatures." The patent explains that "the creep relaxation temperature" is the "point at which the stress relaxation modulus has dropped by a factor of 10 from its low temperature limit." *Id.* at 4:40-42. The patent states that the temperature window "between the material's solidification temperature and its creep relaxation temperature" for ABS is "between approximately 70°C[] and approximately 90°C." *Id.* at 4:63-5:1. By maintaining the temperature of the layers in the vicinity of the newly deposited material in this range, "a balance is struck between the model being so weak that it droops and the model being so stiff that curl stresses (as described above) cause geometric distortions." *Id.* at 5:8-12.

30. Claim 1 of the '058 patent, which I understand is the only asserted independent claim, states as follows:

> A method for making a three-dimensional physical object of a predetermined shape under control of a control system, said method employing a thermally solidifiable material having a solidification temperature and a creep relaxation temperature, said method comprising the steps of:
>
> a) dispensing said thermally solidifiable material in a fluid state from an extruder into a build region having at least a local region temperature that exceeds the solidification temperature of the thermally solidifiable material;
>
> b) simultaneously with the dispensing of the said thermally solidifiable material, and in response to said control system, generating relative movement between the extruder and a support in the build region, so that the said thermally solidifiable material accumulates on said support to form a three-dimensional physical object; and
>
> c) solidifying said thermally solidifiable material by cooling said local region temperature and said material below the solidification temperature of the material.

C. Disputed Claim Terms

1. "solidification temperature"

31. It is my opinion that after reading the '058 patent and prosecution history, one of ordinary skill in the art as of May 1997 would have understood the term "solidification temperature" to mean "temperature at which a material behaves as a solid."

32. As background, some materials, such as water, have distinct transitions between liquid and solid—i.e., when water is above zero degrees it is a liquid and when it is below zero degrees it freezes and, thus, solidifies. The '058 patent, however, involves the use of thermoplastic materials such as ABS. ABS is a glassy material (which is non-crystalline) that does not have a distinct transition from liquid to solid. *See id.* at 3:66-4:11. This is because glassy materials lack an ordered crystalline structure. *See id.* The '058 patent, for example, notes that the invention "is based on the recognition that there is a transition between a material's fluid state and it's solid state." *Id.* at 3:66-4:1. But the patent explains that while "[c]rystalline materials will tend to have sharper transition regions," "glassy materials will exhibit broader transition regions" between the fluid and solid states. *Id.* at 4:4-5.

33. The '058 patent describes a test that was conducted on ABS, which as the patent notes is a thermoplastic material, to identify the solidification temperature. *Id.* at 4:12-18. In particular, a test sample comprised of ABS was subjected to a fixed strain, and as the strain was applied, a commercial rheometer measured the time evolution of the resulting stress on the ABS material. *Id.* at 4:21-23. As explained in the '058 patent, Figure 3B "illustrates the variation of the stress relaxation modulus of an ABS thermoplastic 300 seconds after stress is applied." *Id.* at 4:19-22. The patent explains that "[p]ractically speaking, this is an effective method for determining at what temperature the material is a solid." *Id.* at 4:23-26. The patent then

explains: “FIG. 3B shows that ABS has very little creep over 300 seconds, for temperatures up to about 70°C. This temperature [i.e., 70°C] is therefore defined as the solidification temperature” for ABS. *Id.* at 4:31-33.

34. In other words, the ’058 patent defined the “solidification temperature” of a glassy material based on the stress relaxation modulus testing which “practically speaking” is equivalent to the temperature at which a thermoplastic material behaves as a solid. In addition, based on actual stress relaxation modulus testing done on ABS, the patent defined up to 70°C as the temperatures at which ABS behaves as a solid. The patent, therefore, defined 70°C as the solidification temperature for ABS.

35. Accordingly, in my opinion, after reading the ’058 patent, a person of ordinary skill in the art in May 1997 would have understood the patent to define solidification temperature as the temperature at which a material behaves as a solid. An ordinarily skilled person also would have understood the ’058 patent as disclosing a specific example of this temperature for ABS, when it identifies that at temperatures up to 70°C ABS behaves as a solid.

36. Thus, in my opinion, a person of ordinary skill in the art would have understood claim 1’s term “solidification temperature” to mean “temperature at which a material behaves as a solid.”

2. “thermally solidifiable material”

37. In my opinion, the term “thermally solidifiable material” should have its plain and ordinary meaning. It is a well understand term, which, in the context of claim 1 of the ’058 patent, simply refers to a material that solidifies based on its temperature. In my opinion the term “thermally solidifiable material” is therefore not in need of any additional construction or clarification.

38. If the term must be construed, it is my opinion that a person of ordinary skill in the art as of May 1997 would have understood "thermally solidifiable material" to mean "a material that can undergo a state change, from behaving as a fluid to behaving as a solid."

39. As I described above, the '058 patent "is based on the recognition that there is a transition region between a material's fluid state and it's solid state." '058 patent at 3:66-4:1; *see also id.* at 4:1-11, 4:23-25. The '058 patent also explains that the invention is based on materials transitioning from a fluid state to a solid state based on changes in temperature:

> The system calculates a sequence for extruding ***flowable material that thermally solidifies*** so as to create the desired geometric shape. A heated flowable modeling material is then sequentially extruded at its deposition temperature into a build environment that maintains the volume in the vicinity of the newly deposited material in a deposition temperature window between the material's solidification temperature and its creep temperature. Subsequently the newly extruded material is gradually ***cooled below its solidification temperature***, while maintaining temperature gradients in the geometric shape below a maximum value set by the desired part's geometric accuracy.

Id. at 3:6-19 (emphasis added); *see also id.* at 5:34-36 (invention applies to "flowable material that thermally solidifies").

40. As I explained above, glassy thermally solidifiable materials like ABS do not have distinct transitions from liquid to solid because they lack an ordered crystalline structure. *See id.* at 3:66-4:11. As a result, the '058 patent notes these "materials will exhibit broader transition regions" between the fluid and solid states. *Id.* at 4:4-5. In addition, as I described above, the '058 patent also describes tests used to determine the solidification temperature for ABS, which the patent notes is a thermally solidifiable material. *Id.* at 3:66-4:45. It is at this temperature, the patent says, that the thermally solidifiable material transitions between its fluid state and its solid state. *See id.* at 3:66-4:1, 4:23-25. Thus, at this solidification temperature, the

thermally solidified material is not an actual crystalline solid, but instead simply behaves like one.

41. In my opinion, a person of ordinary skill in the art would have understood the term "thermally solidifiable material" as used in the '058 patent without further definition, and therefore, the plain and ordinary meaning should be used. However, if construction is necessary, it is my opinion that a person of ordinary skill in the art would have understood the term "thermally solidifiable material" to mean "a material that can undergo a state change, from behaving as a fluid to behaving as a solid."

3. "build region"

42. In my opinion, the term "build region" should have its plain and ordinary meaning. It is a well understood term, which, in the context of claim 1 of the '058 patent, simply refers to the region in which a three-dimensional physical object can be built. As a result, in my opinion, the term "build region" is not in need of any additional construction or clarification.

43. If the term must be construed, it is my opinion that after reviewing the '058 patent and prosecution history, a person of ordinary skill in the art in May 1997 would have understood the term "build region" to mean "volume of space in which an object can be built."

44. The language of the claims of the '058 patent supports my opinion that the term "build region" would have meant "volume of space in which an object can be built" to a person of ordinary skill in May 1997. For example, the claims clarify that the three-dimensional printer is "dispensing [the] thermally solidifiable material in a fluid state from an extruder ***into a build region***" to make "***a three-dimensional physical object*** of a predetermined shape." *Id.* at cl. 1 (emphasis added). Thus, the claim language illustrates that the build region is the volume of space in which a three-dimensional object can be built. A person of ordinary skill would have

accordingly understood the term "build region" to mean "volume of space in which an object can be built" in the context of the '058 patent.

45. Similar to the language in the claims, the '058 specification confirms my understanding of the term "build region." As I discussed in detail above, the '058 specification explains that the improved three-dimensional printing system of claim 1 sought to eliminate the geometric distortion that is introduced when a printed prototype cools. *E.g.*, *id.* at 1:42-45. In solving this problem, the patent distinguishes the prior art from the disclosed invention on the basis that the prior art references taught a build environment or region "that is maintained at and below the solidification temperature of the extrusion material." *Id.* at 2:49-61.

46. After describing and distinguishing the prior art, the '058 patent explains that in the disclosed invention, the "heated flowable modeling material is then sequentially extruded at its deposition temperature into a build environment that maintains the volume in the vicinity of the newly deposited material in a deposition temperature window between the material's solidification temperature and its creep temperature." *E.g.*, *id.* at 3:10-19. This disclosure is particularly relevant for the "build region" term because this statement, among many others in the specification, illustrates to one of ordinary skill in the art that the modeling material is deposited into a build environment or region throughout the entire printing process. Indeed, the '058 patent repeatedly describes depositing the modeling material into a build environment or region in order to build the desired prototype or model. *E.g.*, *id.* at Abstract, 3:10-19, 5:36-47 ("FIG 4 shows . . . [a] heated flowable modeling material . . . then sequentially extruded at its deposition temperature into a build environment that maintains the build volume in the vicinity of the newly deposited material in a deposition temperature window defined by the material's solidification temperature and its creep temperature (box 112)."). In other words, like the claims

of the ’058 patent, the ’058 specification makes clear that “build region” refers to the volume of space in which an object can be built—the patent repeatedly and consistently describes “depositing the modeling material into a build environment” to build a prototype. *E.g.*, *id.* at Abstract, 3:10-19, 5:36-47.

47. As a result, based on this disclosure, it is my opinion that if the term “build region” requires construction, a person of ordinary skill in the art would have understood it to mean “volume of space in which an object can be built” in the context of the ’058 patent.

4. “local region temperature”

48. In my opinion, a person of ordinary skill in the art in May 1997 would have understood the term “local region temperature” to mean “temperature in the vicinity of the newly deposited material.”

49. In the specification, the ’058 patent describes that a heated flowable material be extruded “at its deposition temperature into a build environment that maintains the volume in **the vicinity of the newly deposited material** in a deposition temperature window between the material’s solidification temperature and its creep temperature.” *Id.* at Abstract, 3:10-15 (emphasis added). The Summary of the Invention then includes a similar statement: “A heated flowable modeling material is then sequentially extruded at its deposition temperature into a build environment that maintains the volume in **the vicinity of the newly deposited material** in a deposition temperature window between the material’s solidification temperature and its creep temperature.” *Id.* at 3:10-15 (emphasis added). A person of ordinary skill in the art would understand these portions of the specification to describe a region in “the vicinity of the newly deposited material” that is maintained at a temperature above the solidification temperature and below the creep relaxation temperature.

50. Consistent with this disclosure in both the Abstract and the Summary of the Invention, the remainder of the patent focuses on keeping the volume in "the vicinity of the newly deposited material" above the material's solidification temperature. *E.g.*, *id.* at 4:60-65, 5:1-5, 5:36-43. For example, after identifying the specific solidification temperature for ABS, the specification explains that "an entire build layer (outside of the immediate region of the extrusion nozzle) should be maintained above the material's solidification temperature and below the material's creep relaxation temperature." *Id.* at 5:1-5.

51. As described above, the invention of the '058 patent included recognizing that to reduce curl, the temperature of the region in which material is deposited should be maintained above (as opposed to at or below) the solidification temperature of the deposited material. A person of ordinary skill in the art would have therefore understood the above statements from the '058 specification to be describing the importance of a specific region—i.e., "local region" as used in claim 1—of the build environment that is maintained above the solidification temperature of the deposited material and below the creep relaxation temperature.

52. Accordingly, in my opinion, a person of ordinary skill in the art in May 1997 would have understood the term "local region temperature" to mean "temperature in the vicinity of the newly deposited material" in the context of the '058 patent.

5. "cooling"

53. In my opinion "cooling" is a well understood term, which, in the context of claim 1 of the '058 patent, simply refers to cooling the local region from above the solidification temperature to below the solidification temperature. A person of ordinary skill in the art would have understood that there are multiple ways to cool a material, including by simply allowing the

part to cool in the ambient environment. In my opinion the term “cooling” is therefore not in need of any additional construction or clarification—“cooling” means “cooling.”

54. I understand that Afinia has proposed that “cooling” means “reducing temperature at a rate of (dT) that does not violate the equation: $(dT/dz)_{max}=8^{\delta}/L^2a)$.” I disagree with Afinia’s proposed construction. As explained above, “cooling” is a well-understood term that just means cooling. In my opinion, a person of ordinary skill in the art would not have considered the claims of the ’058 patent to require a particular type of cooling.

VIII. DETAILED OPINIONS ON CLAIM CONSTRUCTION ON THE ’124 PATENT

A. Person of Ordinary Skill in the Art

55. I understand that the person of ordinary skill in the art relating to an invention claimed in a patent is a fictitious person presumed to have the typical level of skill of practitioners in the field as of the effective filing date of the patent application, which I understand is January 26, 1998 for the ’124 patent. I understand that many factors are considered in defining a hypothetical person of ordinary skill in the art, including: (1) the types of problems encountered in the art; (2) the prior art solutions to those problems; (3) the rapidity with which innovations are made; (4) the sophistication of the technology; and (5) the educational level of active workers in the field.

56. In my opinion, the ’124 patent generally relates to fused deposition modeling rapid prototyping systems and, in particular, to the design of the liquifier for use in an extrusion head of a fused deposition modeling rapid prototyping system. *See, e.g.*, ’124 patent, 1:4-6 (“This invention relates to a dispensing head for depositing layers of solidifying material in a desired pattern to form three-dimensional physical objects.”).

57. Based on my experience working in the field of fused deposition modeling in the 1990s, a person of ordinary skill in the art as of January 1998 typically would have had a B.S. degree in one of a number of scientific or engineering areas, including chemistry, physics, mechanical engineering, electrical engineering, materials science and engineering, or industrial engineering. In addition, that person would also have had 1-3 years of experience working with fused deposition modeling. The graduate students and Rutgers faculty I worked with on my FDC research and publications were skilled persons, as were others in the research and product development departments for companies who worked in this field at that time. In my opinion, I possessed at least ordinary skill in the art as of January 1998.

B. Background of the Invention

58. As described above in Part VI, a fused deposition modeling printing system makes three-dimensional physical objects by heating thermoplastic material (e.g., ABS plastic) to a temperature at which the plastic becomes flowable. The fused deposition modeling system then deposits the plastic in a flowable state onto a base or platform, where the plastic eventually cools and solidifies. The fused deposition modeling system continues to deposit the next layer and in this fashion creates a three-dimensional object by depositing material one layer at a time. *See generally id.* at 1:12-28.

59. An important component of a fused deposition modeling system is the liquifier, which is the structure within the system where the filament is heated to a flowable state. The invention in the ’124 patent (attached as Exhibit D) relates to the design of the liquifier. In particular, the invention relates to a liquifier design that allows the filament to be heated while in the heating zone (which is the area in the liquifier where the filament is heated to a flowable

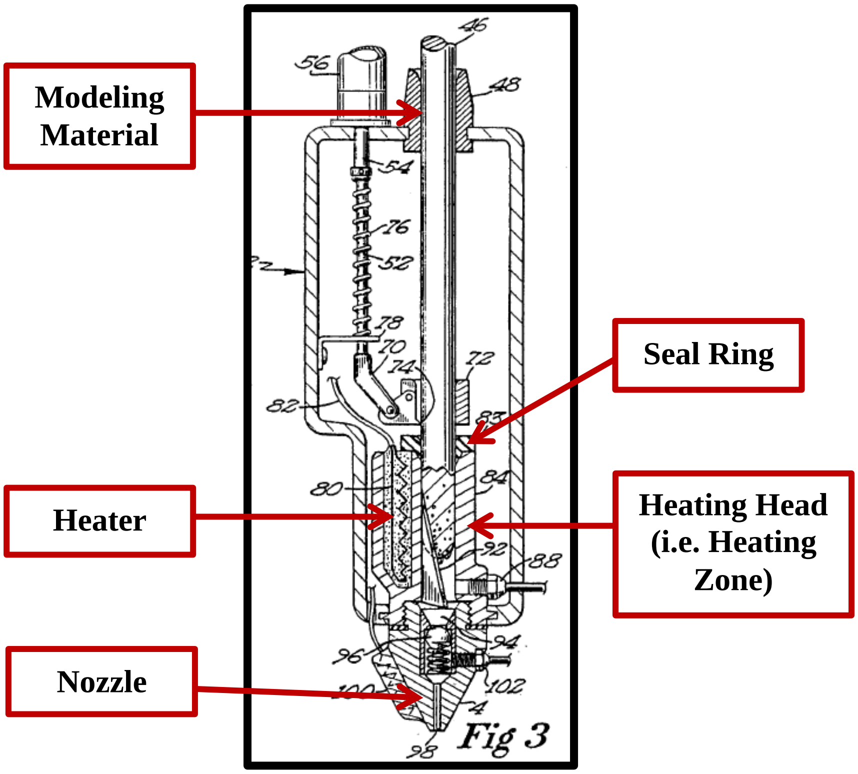
state) while at the same time allowing the heat to dissipate quickly outside of the heating zone so as to avoid prematurely heating the filament before it reaches the heating zone of the liquifier.

60. The specification of the ’124 patent begins by describing prior art references, including U.S. Patent Nos. 5,121,329 and 5,340,433. The specification explains that these references describe an extrusion head for use in three-dimensional printing and in particular, an extrusion head “which receives a solid state material used to form three-dimensional articles, heats the material to just above its solidification temperature, and dispenses the material as a fluid onto a base.” *Id.* at 1:22-29. The specification also describes that the liquifiers taught by these references consist of “three zones: an entrance zone or cap, a heating zone or body and a nozzle.” *Id.* at 1:29-33. The “entrance zone or cap zone” is the first section of the liquifier which serves as a transition for the modeling material filament. The patent describes that at the entrance of the cap zone, the filament is entering the liquifier and should be below the softening point of the material, and at the outlet of the cap zone, the filament should be above the temperature at which the material can be extruded. The “heating zone” refers to the area in which the filament is heated to a flowable state. And the “nozzle” refers to the end of the liquifier where the flowable material is extruded.

61. The ’124 patent explains that in each of these prior art references the liquifier contained a “seal ring” that acted as the “cap” or “cap zone.” *Id.* at 1:32-2:37. The purpose of the “seal ring” was to prevent heat from the heating zone from heating the filament before it entered the heating zone.

62. The ’124 patent discusses Figure 3 from the ’433 patent as an example of a prior art liquifier design. As described in the ’124 patent, Figure 3 from the ’433 patent includes a “seal ring (i.e. a cap), a heating head (i.e., heating zone) and a nozzle.” *Id.* at 1:33-36. Figure 3

from the ’433 patent is shown below, with annotations added for the “seal ring (i.e. a cap),” the “heating head” (i.e. “heating zone”), and “nozzle.” ’433 patent at 7:50-57.



63. As shown above, Figure 3 from the ’433 patent illustrates how a seal ring (or cap) was used in the prior art devices. The filament is shown entering the liquifier through the seal ring. ’124 patent at 1:33-36. The filament then passes into the heating zone where it is heated and transitions to a flowable state. The material then flows into and through the nozzle and is dispensed through the nozzle outlet. *Id.* at 1:36-41.

64. The “seal ring” (or cap) at the top of the heating zone was necessary in the prior art to “serve[] as the transition zone for the modeling material where at the entrance to the cap the temperature is below the softening point of the material and the outlet of the cap is above the temperature required to pump the material in a semi-liquid state.” *Id.* at 2:39-44. In particular, it was important that the filament not soften before it entered the liquifier. This was because significant heating of the filament before it entered the liquifier would result in softening and

buckling of the filament, which would in turn make it difficult (if not impossible) to continue pushing the filament through the extrusion head. *Id.* at 3:18-22. This was an especially challenging problem given the significant change of temperature in the liquifier—as noted in the ’124 patent, it was common to have a change of temperature of about 250° Celsius between the top of the cap zone where the filament enters the liquifier, and the bottom of the cap zone where the liquifier begins heating the filament to a flowable state. *Id.* at 2:39-45. The prior art devices therefore used this “seal” or “seal ring,” which was a special piece of hardware designed to be placed at the top end of the liquifier to prevent heat from the heating block from heating and softening the material above the liquifier.

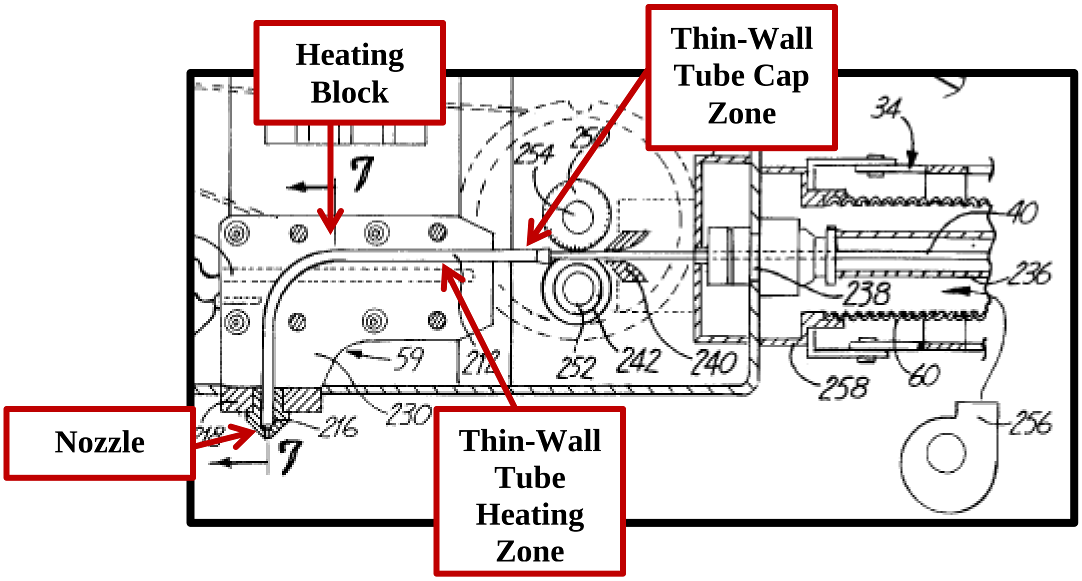
65. The prior art disclosed many different types of seals that were intended to prevent heat from escaping the heating zone, including the Dupont Vespel SP-1 cap. *Id.* at 2:45-51. As shown above, the ’433 patent illustrates “a suitable seal ring 83.” ’433 patent at 7:50-57.

66. However, as explained in the ’124 patent specification, there are disadvantages to using seals or caps. The seals or caps, for example, are “expensive, have temperature limitations, and require a sealing mechanism between the cap and the heating body.” ’124 patent at 2:51-54. As such, the seals and caps “are prone to leakage.” *Id.* In addition, seals do not entirely prevent buckling of the filament above the heating block and consequently do not always serve their intended purpose. In fact, before January 1998, I used a prior art device from Stratasys called the 3D Modeler® and had difficulty keeping the material above the heating block solid enough to prevent buckling, even with the seal. The problem was so significant that I had to blow cold air (from an air conditioning unit) onto the portion of the material above the heating block to inhibit buckling.

67. The invention disclosed in the ’124 patent overcame these problems by developing a liquifier that no long required a seal and instead included “a thin-wall tube liquifier formed of a single piece of thin-wall tubing encased in a heating block,” wherein the “tube acts as both the heating zone and the cap zone of the liquifier.” *E.g.*, *id.* at 2:64-67. In particular, the cap zone refers to the portion of the thin-wall tube that extends outside the heating block, and the heating zone refers to the portion of the thin-wall tube that sits inside the heating block.

68. The improved liquifier is made of a “thin-wall tube [that] has a [sic] inlet end for receiving a filament of molding material and an outlet end for delivering the material in liquid form.” *Id.* at 3:7-9. The disclosed thin-wall tube eliminates the need for the expensive and often ineffective seals. Instead, the invention utilizes a tube thin enough to function as the cap zone and the heating zone without the use of a seal. The ’124 specification explains this general design: “A first section of the tube adjacent the inlet end functions as the entrance or cap zone. This first section of the tube is exterior to the heating block.” *Id.* at 3:9-11; *see also id.* at 11:34-36, 11:39-40. In addition, the tube “has a second section which passes through the heating block forming a heating zone.” *Id.* at 3:11-13; *see also id.* at 11:37-38, 11:40-41. Finally, the “nozzle connects to the outlet end of the tube.” *Id.* at 3:13-14; *see also id.* at 11:38-39, 11:41-42.

69. Below is a cropped image from Figure 8 of the ’124 patent, illustrating the disclosed “thin-wall tube.”



70. The specification discloses that the "cap zone of the tube must dissipate heat rapidly to maintain the flexible strand at a suitable temperature during its movement into the heating zone, so that the strand will not become limp and buckle." *Id.* at 3:19-22. Because the "thin-wall tube" is able to itself perform this function of dissipating heat in the cap zone, the need for a seal between the cap zone and the liquifier body is eliminated. *Id.* at 3:47-50.

71. Claim 1 of the '124 patent, which I understand is one of two asserted independent claims, states as follows:

> An extrusion head for depositing layers of solidifying material in a desired pattern to form three-dimensional physical objects, the extrusion head comprising:
>
> > a heating block made of heat conductive material;
> >
> > a heating element to heat the heating block;
> >
> > a first thin-wall tube having an inlet end for receiving a filament of a first material, an outlet end for delivering the first material in a molten state, and having a first section adjacent the inlet end and exterior to the heating block and a second section which passes through the heating block;
> >
> > a material advancee mechanism positioned to advance the filament of first material into the inlet end of the first thin-wall tube; and
> >
> > a nozzle at the outlet end of the first thin-wall tube for dispensing the first material in a molten state.

72. Claim 17 of the '124 patent, which I understand is the other asserted independent claim, states as follows:

> A liquifier for receiving a filament of material and liquefying the material for deposition in a molten state, comprising:
>
> > a heating block made of heat conductive material;
> >
> > a first thin-wall tube having an inlet end for receiving a filament of a first material, an outlet end for delivering the first material in a molten state, and having a first section adjacent the inlet end and exterior to the heating block and a second section which passes through the heating block; and
> >
> > a nozzle at the outlet end of the first thin-wall tube for dispensing the first material in a molten state.

C. Disputed Claim Terms

1. "thin-wall tube"

73. In my opinion, a person of ordinary skill in the art in January 1998 would have understood "thin-wall tube" to mean "a single piece of tubing with wall thickness that allows the tubing to act as a cap zone and a heating zone."

74. The term "thin-wall tube" appears in the following limitation in claim 1: "a first **thin-wall tube** having an inlet end for receiving a filament of a first material, an outlet end for delivering the first material in a molten state, and having a first section adjacent the inlet end and exterior to the heating block and a second section which passes through the heating block." The claim language describes the "thin-wall tube" as having an inlet, which is where the filament is received, and an outlet, which is where the filament is delivered in a molten state. In between the inlet and the outlet, the claim states that the "thin-wall tube" has a first section that is adjacent the inlet and exterior to the heating block and a second section that passes through the heating block. As described in more detail below, a person of ordinary skill in the art would

have understood the first section (which is exterior to the heating block) as a cap zone and the second section (which is in the heating block) as the heating zone.

75. In particular, a person of ordinary skill in the art would have understood that in the context of the ’124 patent, the “thin-wall tube” was intended to solve the problems with the prior art liquifiers by providing a design that allowed for a cap zone and heating zone in a single tube and without requiring use of a seal. The ’124 specification, for example, explains that the prior art liquifiers included three distinct zones: (1) an entrance zone or cap, (2) a heating zone or body, and (3) a nozzle. *E.g.*, ’124 patent at 1:30-32. The patent also notes that the prior art contained a “seal” or “seal ring” which operated as the cap zone. *Id.* at 1:32-2:37. The patent also explains that these seals served “as the transition zone for the modeling material,” where at the entrance the temperature is below the softening point for the modeling material and at the outlet the temperature is above the temperature required to pump the material in a semi-liquid state. *Id.* at 2:38-44. The inventors further lament that these seals are expensive, have temperature limitations, and are prone to leakage due to the seam between the seal component and the heating block component which is created because they are two distinct pieces. *Id.* at 2:51-54.

76. After describing these problems with the prior art liquifiers, the ’124 patent describes an improved liquifier that includes a single tube with a wall thickness thin enough to eliminate the requirement of the seal and accordingly can serve as both the cap zone and the heating zone of the liquifier. For example, the ’124 patent states in the Summary of the Invention: “The present invention provides a thin-wall tube liquifier formed of a single piece of thin-wall tubing encased in a heating block. The tube acts as both the heating zone and the cap zone of the liquifier.” *Id.* at 2:64-67. The specification repeatedly discusses that the thin-wall

tube has a wall thickness that allows the single tube to act as both a heating zone and a cap zone: "The thin-wall tube has a [sic] inlet end for receiving a filament of molding material and an outlet end for delivering the material in liquid form. A first section of the tube adjacent the inlet end functions as the entrance or cap zone. This first section of the tube is exterior to the heating block. The tube has a second section which passes through the heating block forming a heating zone." *Id.* at 3:7-13; *see also id.* at Abstract ("The liquifier is formed of a single piece of thin-wall tubing preferably made of metal, encased in a heating block. The thin-wall tube has a [sic] inlet end for receiving a filament of molding material and an outlet end for delivering the material in liquid form. A first section of the tube adjacent the inlet end functions as the entrance or cap zone. This first section of the tube is exterior to the heating block. The tube has a second section which passes through the heating block forming a heating zone."); *id.* at 11:34-42 ("When mounted in heating block 214, a first section of tube 212 adjacent the inlet end 224 is exterior to heating block 214, and a second .mid-section of tube 212 is clamped within heating block 214, and a third section of tube 212 including tip 216 extends through the bottom of block 214. The first section of tube 212 forms a cap zone for the liquifier 59, the second section of tube 212 forms a heating zone, and the third section forms a nozzle zone."). The patent explains that the "cap zone of the tube must dissipate heat rapidly to maintain the flexible strand at a suitable temperature during its movement into the heating zone, so that the strand will not become limp and buckle." *Id.* at 3:19-23. The patent also explains that "[i]t is desirable to keep tube 212 as thin as possible to achieve maximum heat transfer across tube 212 to filament 40." *Id.* at 11:20-22. In other words, a person of ordinary skill in the art would have understood that rather than having a liquifier with a separate cap (or seal) zone and heating zone, the inventors claimed a single tube thin enough to act as both a cap zone and a heating zone.

77. A person of ordinary skill in the art would have understood that the '124 patent does not require a specific dimension for the "thin-wall tube," but instead makes clear that the dimension should simply be chosen to ensure that the tube is able to act as both a cap zone (i.e., a zone that prevents heat from escaping the heating zone) and a heating zone (i.e., a zone that heats the filament such that it liquefies). For example, the patent states that the "cap zone of the tube must dissipate heat rapidly to maintain the flexible strand at a suitable temperature during its movement into the heating zone, so that the strand will not become limp and buckle." *Id.* at 3:19-23. The patent later states that "[i]t is desirable to keep tube 212 as thin as possible to achieve maximum heat transfer across tube 212 to filament 40." *Id.* at 11:20-22.

78. While the patent gives examples of particular dimensions, such as 0.005 to 0.015 inches, the patent is clear that such examples are "preferable" and therefore not necessarily required by the invention. *Id.* at 11:19-20. In my opinion, a person of ordinary skill would clearly understand that the exact dimension selected is not important to the invention provided that the single tube is able to act as both a cap zone and a heating zone—i.e., heating the filament in the heating zone while at the same time preventing the heat from traveling up the filament into the cap zone and causing the buckling that was so prevalent in the prior art. Indeed, the exact thickness selected for the tube would depend on a number of factors, including, for example, the material used for the tube, the length of the tube, the type of filament used, and the temperature of the heating zone in the liquifier. To take one basic example, the preferred embodiment uses a stainless steel tube. *Id.* at 3:22-25. A person of ordinary skill in the art would recognize that if the tube was constructed of a different material (e.g., copper or aluminum), the thickness of the tube would need to be adjusted in order to perform the cap zone and heating zone functions. Moreover, a person of ordinary skill in the art would be able to determine if a tube is thin enough

to serve as both a cap zone and a heating zone with minimal experimentation. In addition, the ’124 patent expressly acknowledges that this is the case: “Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.” *Id.* at 12:63-67.

79. For reasons I stated above, I also disagree with Afinia’s proposed construction of “thin wall.” In particular, I disagree that a person of ordinary skill in the art would understand the term “thin wall” or “thin-wall tube” as identifying a particular range of thicknesses after reading the ’124 patent and prosecution history. To the contrary, it is my opinion that the patent clearly indicates to a person of ordinary skill that the ranges disclosed in the patent specification are preferred thickness ranges. For example, each time the patent discusses actual thickness ranges, it clarifies that the range is simply a preferred thickness. *E.g.*, *id.* at 3:22-26 (“A stainless steel tube having a wall thickness in the range of 0.008-0.015 inches ***is suitable*** and inexpensive for this purpose.” (emphasis added)); *id.* at 11:18-19 (“The wall thickness of tube 212 ***is preferably between*** 0.005–0.015 inches.” (emphasis added)). In addition, for the reasons explained above, a person of ordinary skill in the art would have understood that a variety of wall thicknesses could be used, provided that the thickness was such as to allow the tube to act as a cap zone and heating zone.

80. I also note from my review of the ’124 prosecution history (attached as Exhibit I) that the inventors and Patent Office examiner understood that the “thin-wall tube” referred to a single tube that provided a cap zone and a heating zone and thereby eliminated the need for a seal. In particular, in the examiner’s Notice of Allowance, he stated: “The closest prior art (Crump: 5,340,433) discloses an extrusion head as shown in figure 13 having a guide tube

(244), a seal (248) and a liquifier (226). It is clear that the reference fails to teach a heating block containing a thin wall tube wherein an inlet end of the liquifier is exterior of the heating block and a second portion of the tube is within the heating block." 6/8/1999 Examiner Notice of Allowance (Exhibit I at STS0000042).

81. Accordingly, for all of these reasons, in my opinion, a person of ordinary skill in the art would have understood the term "thin-wall tube" as used in claim 1 to mean "a single piece of tubing with wall thickness that allows the tubing to act as a cap zone and a heating zone."

IX. DETAILED OPINIONS ON CLAIM CONSTRUCTION ON THE '239 PATENT

A. Person of Ordinary Skill in the Art

82. I understand that the person of ordinary skill in the art relating to an invention claimed in a patent is a fictitious person presumed to have the typical level of skill of practitioners in the field as of the effective filing date of the patent application, which I understand is September 23, 2009 for the '239 patent. I understand that many factors are considered in defining a hypothetical person of ordinary skill in the art, including: (1) the types of problems encountered in the art; (2) the prior art solutions to those problems; (3) the rapidity with which innovations are made; (4) the sophistication of the technology; and (5) the educational level of active workers in the field.

83. In my opinion, the '239 patent generally relates to fused deposition modeling rapid prototyping systems and, in particular, to a method for building a three-dimensional model that uses a deposition pattern that effectively conceals seams and increases the aesthetic and functional qualities of the model. *See, e.g.*, '239 patent at 2:66-3:7.

84. Based on my experience working in the field of fused deposition modeling in the late 2000s, a person of ordinary skill in the art as of September 2009 typically would have had a B.S. degree in one of a number of scientific or engineering areas, including chemistry, physics, mechanical engineering, electrical engineering, materials science and engineering, or industrial engineering. In addition, that person would also have had 1-3 years of experience working with fused deposition modeling. That person may also work in collaboration with other scientists or engineers who have experience working with and writing computer code. The graduate students and Rutgers faculty I worked with on my FDC research and publications were skilled persons, as were others in the research and product development departments for companies who worked in this field at that time. In my opinion, I possessed at least ordinary skill in the art as of September 2009.

B. <u>Background of the Invention</u>

85. As described above in Part VI, a fused deposition modeling printing system makes three-dimensional physical objects by heating thermoplastic material (e.g., ABS plastic) to a temperature at which the plastic becomes flowable. The fused deposition modeling system then deposits the plastic in a flowable state onto a base or platform, where the plastic eventually cools and solidifies. The fused deposition modeling system continues to deposit the next layer which fuses to the previously deposited material, and in this fashion creates a three-dimensional object by depositing material one layer at a time. *See generally id.* at 1:11-25.

86. The fused deposition modeling system deposits material through the nozzle of an extrusion head. The extrusion head path is controlled by a computer that contains build data representing the desired three-dimensional model. *Id.* at 1:26-28. The build data is obtained by slicing the desired computer model into multiple horizontal layers. *Id.* at 1:28-30. The computer

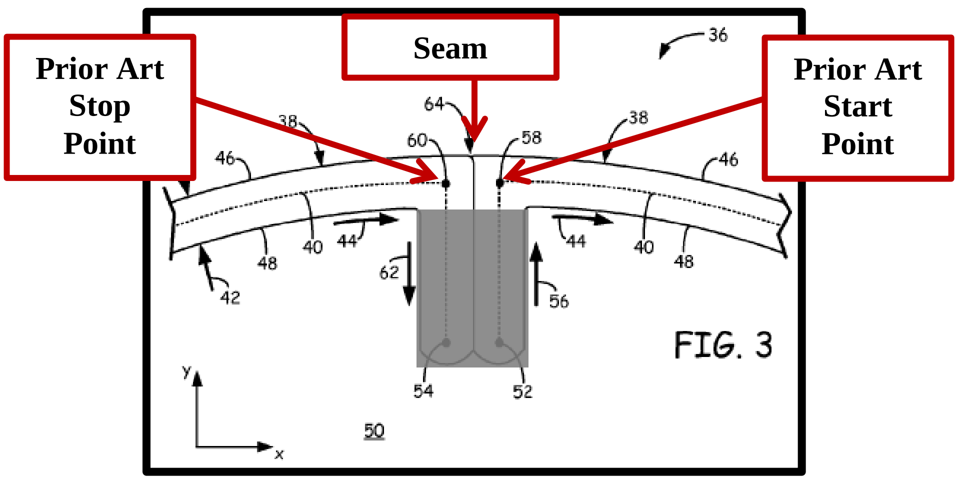
uses that data to control the extrusion head's movement along tool paths, along which modeling material is deposited in roads. *Id.* at 1:30-33. The extrusion head follows the tool path for each layer and accordingly deposits the modeling material along the tool path in response to commands from the computer. As a result, the path the extrusion head follows as it deposits material defines the shape and dimensions of the three-dimensional model.

87. Because the path of the extrusion head defines the printed model, that path is critical to the accuracy and aesthetics of the model. The '239 patent (attached as Exhibit E) discloses a method of adjusting the tool path for a three-dimensional model to "effectively conceal[] the seam that is formed" by the prior art tool paths, "which can increase the aesthetic and functional qualities of the resulting 3D model." *Id.* at 3:4-7. The '239 patent discusses two different types of tool paths. First, the patent explains that "**contour** tool paths . . . define the perimeter(s) of 3D model[s]." *Id.* at 5:3-4 (emphasis added). Contour tool paths generally have a start point and a stop point where the modeling material begins being deposited and stops being deposited. *Id.* at 1:63-2:2, 6:17-23. The patent also describes that additional tool paths "e.g., **raster** paths" will "fill in the interior region(s) defined by the perimeter(s), as necessary." *Id.* at 5:11-14. Thus, either of these tool paths can be manipulated to change the functionality and aesthetics of a model.

88. The '239 patent discusses how the prior art references created contour tool paths and raster paths for use in three-dimensional modeling systems. *Id.* at 6:39-7:2. In particular, in the printing technique used in the prior art to the '239 patent, the start and stop points of the contour tool paths were collinear with the outer ring of the contour tool paths—i.e., both the start point and the stop point were on the perimeter of the layer. *Id.* at 6:39-43. This path was

"typically generated to match the geometry of the exterior perimeter of a 3D model layer." *Id.* at 6:44-46.

89. The '239 patent describes the prior art in reference to Figure 3, an annotated version of which is shown below. The patent, for example, describes how the "stop point would end up being located next to the start point (e.g., at points 58 and 60)," as shown in my annotated Figure 3 below. *Id.* at 6:49-51. In other words, in the prior art, the start point and stop point formed a butt joint on the perimeter of the layer. Note that I shaded out the portion of the contour tool path on the interior of the perimeter in Figure 3 below. This is because, as described in the '239 patent, this portion of Figure 3 was not in the prior art.



90. Placing the start point and stop point next to one another, as was typical in the prior art, can create an issue called "bumping." *Id.* at 6:52-56. For example, because the extrusion head does not always extrude modeling material at a perfect rate, excess modeling material deposited at the stop point may overlap with excess modeling material that was deposited at the start point when the start and stop points are located side-by-side. *Id.* This "bumping" can form bulges at the seam between the start and stop points which can be visually observed from the outside of the printed model. *Id.* at 6:56-59.

91. This start and stop point placement can also produce gaps at the seam between the points. *Id.* at 6:59-62. Gaps can be formed when the flow rate of the modeling material is too slow or where the stop and start points are too far apart for the given flow rate. In certain applications these gaps create a functional problem with the printed model. Specifically, gaps increase the porosity of the model at the seam and can consequently "allow gases and fluids to pass into or through the 3D model, which may be undesirable for many functional purposes (e.g., for containing liquids)." *Id.* at 6:59-65. Thus, both bumps and gaps can negatively impact the functionality and aesthetics of a model.

92. The '239 patent discloses a method for overcoming the problems in the prior art associated with butt joints, gaps, and bumping. In particular, the '239 specification discloses a method for concealing seams between start points and stop points by adjusting the location of the start point and/or the stop point such that the start point and/or stop point is located on the interior rather than the perimeter. By adjusting the start points and/or the stop points, "any variations in the extrusion process when starting and stopping the depositions occur at a location that is within interior region 50 rather than adjacent to exterior surface 46." *Id.* at 7:6-10. In other words, any bumps or gaps "that occur within interior region 50 are masked by the successive layers of 3D model 26, thereby concealing these effects within the filled body of 3D model 26 when completed." *Id.* at 7:10-13. As a result, as explained in the '239 patent, the dimensions of the perimeter path at the seam are truer to the dimensions of the digital representation of 3D model, which also improves the consistency of the seams throughout successive layers of a 3D model. *See id.* at 7:13-16. Moreover, the deposited modeling material thereby forms a seam that is sealed and extends inward within the interior region, which in turn

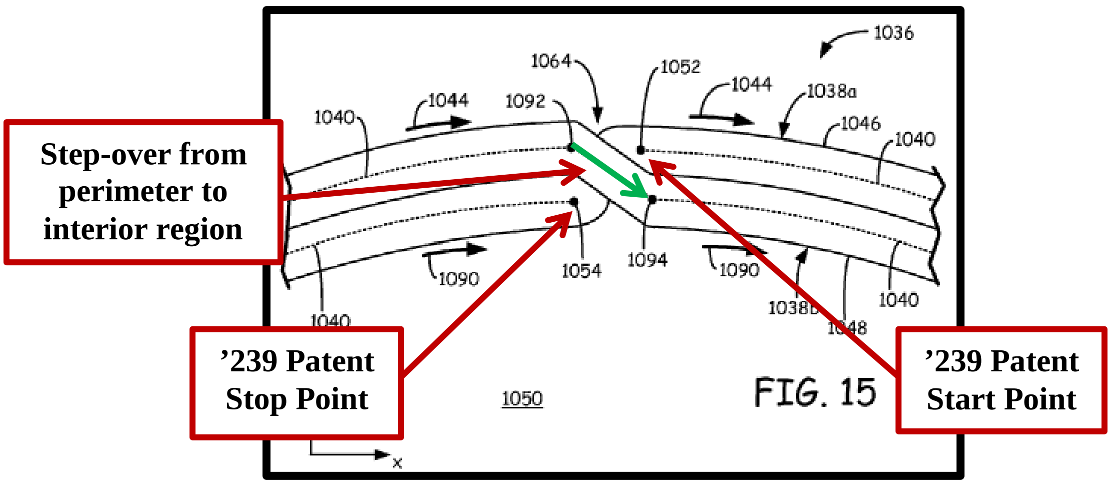
reduces the surface porosity of the 3D object that is being printed, thereby "reducing or eliminating the transmission of gases and/or liquids through seam." *See id.* at 7:35-40.

93. The '239 specification explains that to adjust the start and stop points for each layer, the system "generates one or more contour tool paths based on the perimeter of the layer." *Id.* at 7:62-64. The system then adjusts "the locations of the start point and/or end point [for the layer] to coordinate locations that are within the interior region for each generated contour tool path." *Id.* at 8:6-9. After one or both of the start and stop points are "positioned in the interior region of the layer," the system generates "additional tool paths (e.g., raster paths) to bulk fill the interior region" to account for moving the start and stop points of the contour tool path to the interior region. *Id.* at 8:17-24. While building the three-dimensional model, the extrusion head "follows the patterns of the tool paths for each layer, including the contour tool paths with the adjusted start and stop points." *Id.* at 8:32-35. As such, each layer "may include a concealed seam having start and stop points located within the interior region of the given layer." *Id.* at 8:35-38.

94. The '239 patent describes multiple embodiments of the disclosed invention, including several examples of adjusting the start and/or stop points to the interior region of a layer. *Id.* at 8:41-13:7. For example, the '239 patent describes an embodiment in which two perimeter paths are "deposited by extrusion head 20 along contour tool path 1040 in two passes." *Id.* at 11:63-12:4. In this embodiment, the thickness of the perimeter path increases and the interior region decreases.

95. An example of this embodiment is illustrated in Figure 15, which I annotated below. The '239 patent describes this example as showing "contour tool path 1040 [that] includes start point 1052 and stop point 1054, where stop point 1054 is located within interior

region 1050." *Id.* at 12:15-17. It further explains that the extrusion head moves along the contour tool path "until reaching point 1092" where, "while continuing to deposit the modeling material, extrusion head 20 steps over from perimeter path 1038a to begin forming perimeter path 1038b at point 1094." *Id.* at 12:17-25. The patent, therefore, describes creating a step-over arrangement between the start point and the stop point, and this step-over arrangement creates an improved seam.



96. Figure 14, which I include below, shows a high-level view of the contour tool path and step over illustrated in Figure 15. The patent also discloses that "the step-over arrangement may be continued to form additional perimeter paths" and consequently continue "increasing the overall thickness of the perimeter paths." *Id.* at 12:46-49.

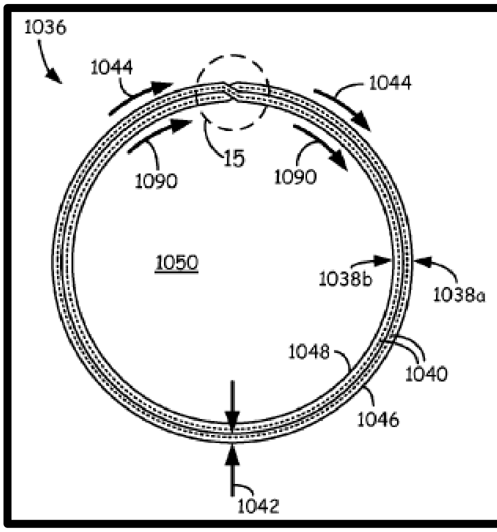
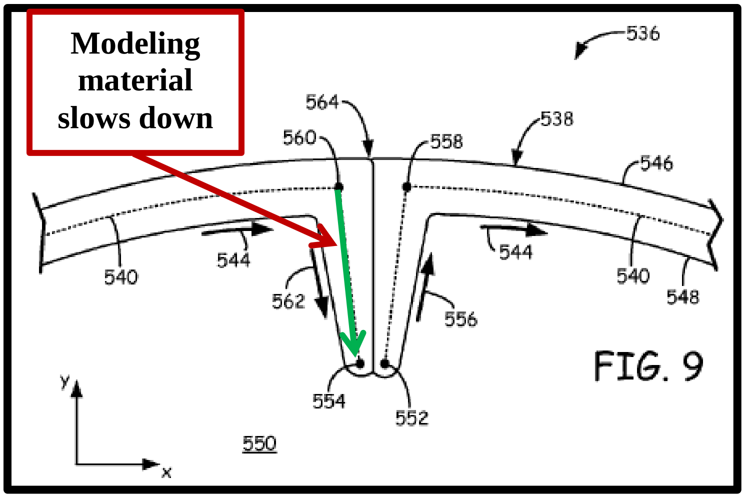


FIG. 14

97. The ’239 patent also describes embodiments that require the rate at which the modeling material is extruded to be significantly decreased as the extrusion head approaches “the intersection of start point 252 and stop point 254.” *Id.* at 9:14-21. In particular, the patent explains that “as extrusion head 20 travels along contour tool path 540 in the direction of arrow 562 between point 560 and stop point 554, the volumetric flow rate may gradually decrease” to allow “proper amounts of modeling material to be deposited at seam 564 and also reduce[] the amount of modeling material that is accumulated along the vertical z-axis at the intersection between start point 552 and stop point 554.” *Id.* at 10:8-18; *see also id.* at 10:26-33, 10:44-49. I illustrate this example in Figure 9 below, which I annotated. Collectively, these embodiments illustrate that different paths can be used to fulfill the claimed invention. Thus the examples given in Figures 3-16 do not constitute the totality of the ways in which the contour tool path can be modified so as to create more accurate models, but are only intended as a set of examples. *See id.* at 14:4-7.



98. Claim 1 of the ’239 patent, which I understand is one of two asserted independent claims, states as follows:

> A method for building a three-dimensional model with an extrusion-based digital manufacturing system, the method comprising generating a contour tool path that defines an interior region of a layer of the three-dimensional model, wherein the contour tool path comprises a start point, a stop point, and a step-over arrangement between the start point and the stop point, wherein the step-over arrangement is oriented at a non-right angle, wherein at least one of the start point and the stop point is located within the interior region of the layer, and wherein the step-over arrangement reduces surface porosity for the three-dimensional model.

99. Claim 15 of the ’239 patent, which I understand is the other asserted independent claim, states as follows:

> A method for building a three-dimensional model with an extrusion-based digital manufacturing system, the method comprising:
>
> generating a tool path that comprises:
>
> a start point for the tool path;
>
> a stop point for the tool path;
>
> a contour tool path extending from the start point and based on a perimeter of a layer of the three-dimensional model, wherein the generated contour tool path defines an interior region of the layer; and

> > an interior raster path extending from the contour tool path within the interior region of the layer, wherein the interior raster path ends at the stop point; and
>
> extruding a material in a pattern based on the generated tool path to form the perimeter and at least a portion of the interior of the layer of the three-dimensional model.

C. Disputed Claim Terms

1. "generating"

100. In my opinion "generating" is a well understand term, which, in the context of claims 1 and 15 of the '239 patent, simply refers to the step of generating a contour tool path (claim 1) or generating a tool path (claim 15). A person of ordinary skill in the art would have understood how to generate a contour tool path based on the disclosure in the patent. In my opinion the term "generating" is therefore not in need of additional construction or clarification—"generating" means "generating."

2. "interior region of a layer"/"interior region of the layer"

101. In my opinion, the phrases "interior region of a layer" and "interior region of the layer" should have their plain and ordinary meaning. They are both well understood terms, which, in the context of claims 1 and 15 of the '239 patent, simply refer to a region on the interior of a layer. Consequently, in my opinion the phrases "interior region of a layer" and "interior region of the layer"[1] are therefore not in need of additional construction or clarification.

102. If the phrase must be construed, it is my opinion that a person of ordinary skill in the art in September 2009 would have understood "interior region of a layer" to mean "an area defined by a perimeter of the layer."

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[1] For simplicity, I will refer to both phrases as a single phrase—"interior region of a layer"—in this section of my declaration.

103. The ’239 patent consistently refers to the phrase “interior region of a layer” as the area of a layer “defined by the perimeter” of the layer. *Id.* at 2:8-11, 5:11-19; *see also id.* at 6:12-16 (stating the interior region is “the region of layer 36 confined within perimeter path 38”), 12:10-14 (explaining the interior region “is the region of the layer 1036 confined within perimeter paths 1038a and 1038b”). Moreover, the patent repeatedly describes the disclosed invention as “having a perimeter based on a contour tool path that defines an interior region of a layer.” *Id.* at Abstract; *see also id.* at 1:63-2:2 (stating “the perimeter has a start point and a stop point, and defines the interior region of the layer”).

104. Based on these statements in the specification, it is my opinion that an ordinarily skilled person in September of 2009, after reading the ’239 patent and prosecution history, would have understood “interior region of a layer” to mean the area of a layer defined by the perimeter of that layer. Accordingly, in my opinion, a person of ordinary skill in the art would have understood that in the context of the ’239 patent, the term “interior region of a layer” means “an area defined by a perimeter of the layer.”

3. “start point”

105. The term “start point” is used in the following claim limitation of claim 1: “wherein the contour tool path comprises a start point, a stop point, and a step-over arrangement between the start point and the stop point.” In my opinion, in this context, a person of ordinary skill in the art in September of 2009 would have understood “start point” to mean “point where the contour tool path begins” in claim 1 of the ’239 patent. The term “start point” is also used in claim 15 in the following claim limitation: “a start point for the tool path.” In my opinion, in

this context, a person of ordinary skill in the art in September of 2009 would have understood "start point" to mean "point where the tool path begins" in claim 15 of the '239 patent.[2]

106. As explained above, the '239 patent describes the prior art "in which the start and stop points would typically be collinear with the outer ring" of the contour tool path and states that under this "conventional technique, a contour tool path is typically generated to match the geometry of the exterior perimeter of a 3D model layer." *Id.* at 6:33-51. The patent discusses that this configuration of start and stop points creates bumps and gaps which are visible to an observer. *Id.* at 6:52-7:2. The patent specification explains that the invention disclosed in the '239 patent reduces or eliminates these defects by adjusting "the start point and/or the stop point of each contour tool path of the layer to one or more locations that are within an interior region of a layer defined by the respective contour tool path." *Id.* at 5:4-8.

107. In describing the differences between the prior art and the present invention, the '239 specification states that the disclosed process "provides a continuous road of the deposited modeling material at all locations around the perimeter path 38 except at the intersection between points 58 and 60, where the outgoing and incoming roads meet. This intersection forms a seam for layer 36." *Id.* at 6:33-37. In a preferred embodiment of the disclosed invention, "start point 52 and stop point 54 are each located at an offset location from seam 64 within interior region 50." *Id.* at 6:36-39. Thus, it is clear based on a reading of the '239 patent that the contour tool

[2] For simplicity, I discuss only the use of "start point" in claim 1 of the '239 patent. The only difference between the use of the term in claim 1 and that in claim 15 is that "start point" refers to the start point of a "**contour** tool path" in claim 1 while it refers to the start point of a "tool path" in claim 15. This difference does not affect my claim construction analysis because the terms are used similarly in the patent—both refer to the beginning of the path they reference. *See, e.g.*, '239 patent at 8:32-38 ("During the build operation, extrusion head 20 follows the patterns of the tool paths for each layer, including the contour tool paths with the adjusted start and stop points. As such, each layer of 3D model 26 and/or of support structure 28 may include a concealed seam having start and stop points located within the interior region of the given layer.").

path results in a "continuous road" that begins with a start point and ends with a stop point, where at least one of the points is located in the interior region of the layer. *See id.*

108. In the description of the prior art the '239 specification states that "[d]ue to variations in the extrusion process when starting and stopping the depositions, the modeling material deposited at a stop point corresponding to point 60 may bump into the modeling material previously deposited at a start point corresponding to point 58." *Id.* at 6:52-56. Furthermore, in describing the benefits of the claimed invention over the prior art, the specification states that "by adjusting the location of the start point from point 58 to point 52, and by adjusting the location of the stop point from point 60 to point 54," any "variations in the extrusion process when starting and stopping the depositions [will] occur at a location that is within interior region 50 rather than adjacent to exterior surface 46." *Id.* at 7:3-10. These descriptions again confirm that the start point is the beginning of the contour tool path.

109. The patent also repeatedly references the start point as the point where the contour tool path "begins." *Id.* at 6:17-20, 6:23-25. For example, in discussing Figure 3, the specification clarifies that the extrusion head "begins depositing the modeling material at start point 52" and moves along the contour tool path "in the direction of arrow 62 until reaching stop point 54, where extrusion head 20 stops depositing the modeling material." *Id.* at 6:23-32. In addition, in describing performance of the claimed method as shown in Figure 6, the '239 patent states that the extrusion head "travels along contour tool path 240 between start point 252" and subsequent points along the contour tool path, including the stop point. *Id.* at 9:6-11.

110. To the extent Afinia is attempting to require that the start point be solely determined by reference to computer instructions, I disagree with their proposed construction. Certainly one would expect to find computer instructions associated with the start and stop points

as the ‘239 specification indicates. *Id.* at 6:17-25 (“[S]tart point 52 is a first location in the x-y plane at which extrusion head 20 is directed to begin depositing the modeling material, and stop point 54 is a second location in the x-y plane at which extrusion head 20 is directed to stop depositing the modeling material.”). But in my experience, one of skill in the art would generally be able to determine where the contour tool path started and stopped either by examining a printed model or by watching a printer deposit material, or some combination of those two methods. Moreover, the examination of computer instructions alone is likely insufficient to determine the start point and could lead to errors in making this determination. Some real world observation is likely to be required to determine when deposition of a road of modeling material begins so that the start of the tool path may be identified. In other words, in my view some real world observation is likely required to understand the practical effect of the computer instructions on the printing process. The ‘239 specification is also consistent with my understanding. *E.g.*, 6:31-32 (“[S]top point 54, where extrusion head 20 stops depositing the modeling material.”), 7:35-37 (“The locations of the start point 52 and stop point 54 also allow the deposited modeling material to form a seal at seam 64 that extends inward within the interior region 50.”), 10:26-28 (“For example, the volumetric flow rate may be decreased from 100% of the standard operational rate at point 660 down to zero at stop point 654.”), 12:22-25 (“At this point, while continuing to deposit the modeling material, extrusion head 20 steps over from perimeter path 1038a to begin forming perimeter path 1038b at point 1094.”).

111. Based on this disclosure, it is my opinion that a person of ordinary skill would have understood “start point” to mean the point at which the contour tool path begins in the context of the ’239 patent. Accordingly, a person of ordinary skill in the art in September 2009

would have understood the term "start point" in the '239 patent to mean "point where the contour tool path begins."

4. "stop point"

112. The term "stop point" is used in the following claim limitation of claim 1: "wherein the contour tool path comprises a start point, a stop point, and a step-over arrangement between the start point and the stop point." It is my opinion that after reading the '239 patent and prosecution history, one of ordinary skill in the art as of September 2009 would have understood the term "stop point" in claim 1 to mean "point where the contour tool path ends." The term "stop point" is also used in claim 15 in the following claim limitation: "a stop point for the tool path." In my opinion, a person of ordinary skill in the art in September of 2009 would have understood "stop point" in claim 15 to mean "point where the tool path ends."[3]

113. As I detailed above, the '239 patent describes the prior art "in which the start and stop points would typically be collinear with the outer ring" of the contour tool path and states that with this technique, "the stop point would end up being located next to the start point" on that path. *Id.* at 6:33-51. The patent explains that this configuration of start and stop points creates bumps and gaps which are visible to the observer and which improperly seal at the point where the start point and stop point intersect. *Id.* at 6:52-7:2. The patent specification explains that invention disclosed in the '239 patent eliminates these defects by adjusting "the start point

[3] For simplicity, I discuss only the use of "stop point" in claim 1 of the '239 patent. The only difference between the use of the term in claim 1 and that in claim 15 is that "stop point" refers to the stop point of a "**contour** tool path" in claim 1 while it refers to the stop point of a "tool path" in claim 15. This difference does not affect my claim construction analysis because the terms are used similarly in the patent—both refer to the end of the path they reference. *See, e.g.*, '239 patent at 8:32-38 ("During the build operation, extrusion head 20 follows the patterns of the tool paths for each layer, including the contour tool paths with the adjusted start and stop points. As such, each layer of 3D model 26 and/or of support structure 28 may include a concealed seam having start and stop points located within the interior region of the given layer.").

and/or the stop point of each contour tool path of the layer to one or more locations that are within an interior region of a layer defined by the respective contour tool path." *Id.* at 5:4-8.

114. As I also described above, the '239 specification states that the disclosed process "provides a continuous road of the deposited modeling material at all locations around the perimeter path 38 except at the intersection between points 58 and 60, where the outgoing and incoming roads meet. This intersection forms a seam for layer 36." *Id.* at 6:33-37. In a preferred embodiment of the disclosed invention "start point 52 and stop point 54 are each located at an offset location from seam 64 within interior region 50." *Id.* at 6:36-39. Thus, it is clear based on a reading of the '239 patent that the contour tool path results in a "continuous road" that begins with a start point and ends with a stop point. *See id.*

115. In the description of the prior art the '239 specification states that "[d]ue to variations in the extrusion process when starting and stopping the depositions, the modeling material deposited at a stop point corresponding to point 60 may bump into the modeling material previously deposited at a start point corresponding to point 58." *Id.* at 6:52-56. Furthermore, in describing the benefits of the claimed invention over the prior art, the specification states that "by adjusting the location of the start point from point 58 to point 52, and by adjusting the location of the stop point from point 60 to point 54," any "variations in the extrusion process when starting and stopping the depositions [will] occur at a location that is within interior region 50 rather than adjacent to exterior surface 46." *Id.* at 7:3-10. Still further, the specification clarifies that the extrusion head "begins depositing the modeling material at start point 52" and moves along the contour tool path "in the direction of arrow 62 until reaching stop point 54, where extrusion head 20 stops depositing the modeling material." *Id.* at 6:23-32.

These disclosures further confirm that the stop point is the end of the deposition of the contour tool path.

116. To the extent Afinia is attempting to require that the stop point be solely determined by reference to computer instructions, I disagree with their proposed construction. Certainly one would expect to find source code or computer instructions associated with the start and stop points as the '239 specification indicates. *Id.* at 6:17-25 ("[S]tart point 52 is a first location in the x-y plane at which extrusion head 20 is directed to begin depositing the modeling material, and stop point 54 is a second location in the x-y plane at which extrusion head 20 is directed to stop depositing the modeling material."). But in my experience, one of skill in the art would generally be able to determine where the contour tool path started and stopped either by examining a printed model or by watching a printer deposit material, or some combination of those two methods. Moreover, the examination of computer instructions alone is likely insufficient to determine the stop point and could lead to errors in making this determination. Some real world observation is likely to be required to determine when deposition of a road of modeling material ends so that the stop point of the tool path may be identified. In other words, in my view some real world observation is likely required to understand the practical effect of the computer instructions on the printing process. The '239 specification is also consistent with my understanding. *E.g.*, 6:31-32 ("[S]top point 54, where extrusion head 20 stops depositing the modeling material."), 7:35-37 ("The locations of the start point 52 and stop point 54 also allow the deposited modeling material to form a seal at seam 64 that extends inward within the interior region 50."), 10:26-28 ("For example, the volumetric flow rate may be decreased from 100% of the standard operational rate at point 660 down to zero at stop point 654."), 12:22-25 ("At this

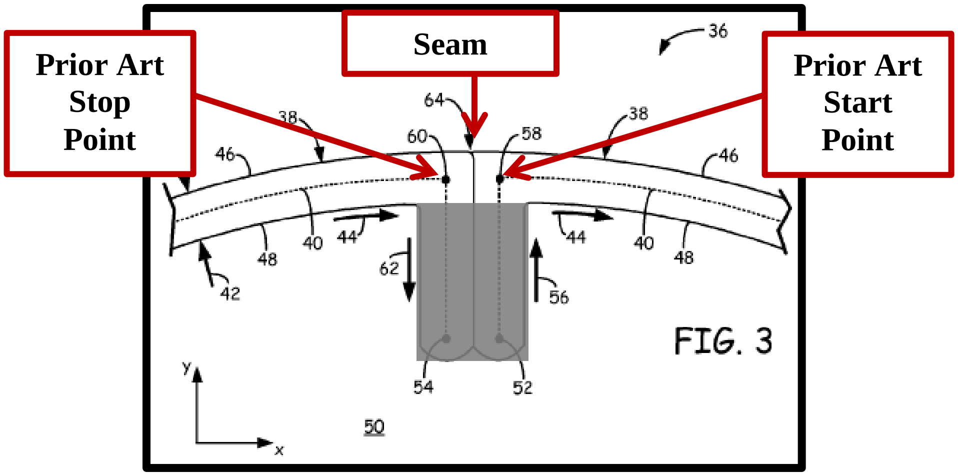
point, while continuing to deposit the modeling material, extrusion head 20 steps over from perimeter path 1038a to begin forming perimeter path 1038b at point 1094.").

117. Accordingly, in my opinion, a person of ordinary skill in the art in September 2009 would have understood "stop point" in claim 1 to mean "point where the contour tool path ends" and the term "stop point" in claim 15 to mean "point where the tool path ends" in the context of the '239 patent.

5. "step-over arrangement"

118. It is my opinion that after reading the '239 patent and prosecution history, one of ordinary skill in the art as of September 2009 would have understood the term "step-over arrangement" to mean "the intersection where the tool path steps from a perimeter to an interior or from an interior to a perimeter."

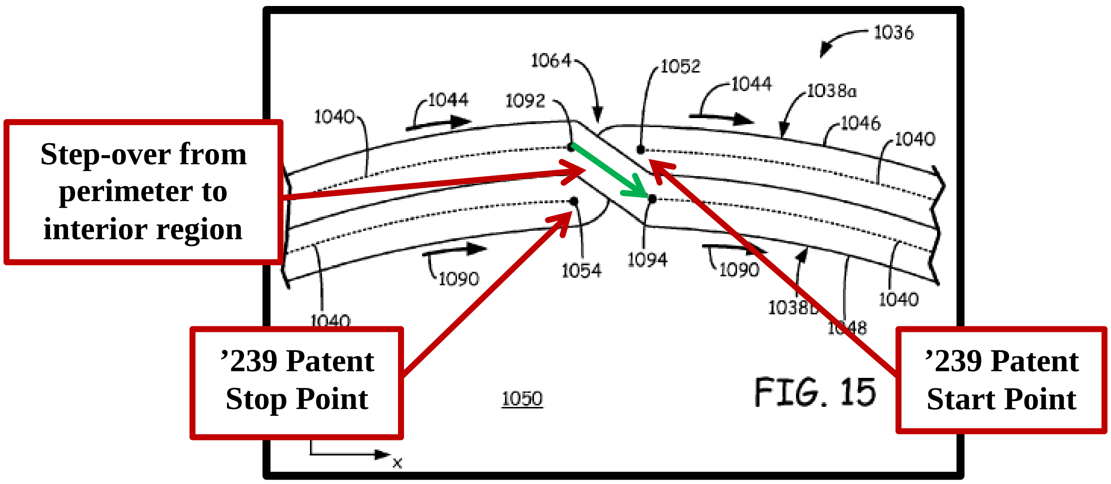
119. In the prior art discussion in the '239 patent, the specification discusses how the prior art references created contour and raster paths for use in three-dimensional modeling systems. *Id.* at 6:39-7:2. In particular, the printing technique used in the prior art created start and stop points on the contour tool path that were collinear with the outer ring of that path. *Id.* at 6:39-43. This path was "typically generated to match the geometry of the exterior perimeter of a 3D model layer," so the "stop point would end up being located next to the start point (e.g., at points 58 and 60)," as shown in my annotated Figure 3 below (again with a shaded-out portion that was not in the prior art). *Id.* at 6:46-51. This start and stop point configuration produced seam 64 on the outside of the printed model, as shown below. This start and stop point configuration also created several issues, including bumps and gaps, as I explained in detail above. *Id.* at 6:52-65. Both bumps and gaps can negatively impact the functionality and aesthetics of a model. *Id.*



120. The patented invention solved these problems with a method for concealing seams between start points and stop points by adjusting the start points and/or the stop points, such that "any variations in the extrusion process when starting and stopping the depositions occur at a location that is within interior region 50 rather than adjacent to exterior surface 46." *Id.* at 7:6-10. As a result of the adjusted start and stop points, the dimensions of the perimeter path at the seam are truer to the dimensions of the digital representation of 3D model, which also improves the consistency of the seams throughout successive layers of a 3D model. *See id.* at 7:13-16. Moreover, "the deposited modeling material [forms] a seal at seam 64 that extends inward within interior region 50" which "reduces the porosity of 3D model 26 at seam 64, thereby reducing or eliminating the transmission of gases and/or liquids through seam 64." *Id.* at 7:35-40. Any bumps "that occur within interior region 50 are masked by the successive layers of 3D model 26, thereby concealing these effects within the filled body of 3D model 26 when completed." *Id.* at 7:10-13.

121. Figure 15, which I annotated below, is an example of the claimed adjusted start and stop points with the claimed step-over arrangement. The '239 patent describes this example as showing "contour tool path 1040 [which] includes start point 1052 and stop point 1054, where stop point 1054 is located within interior region 1050." *Id.* at 12:15-17. It further explains that

the extrusion head moves along the contour tool path "until reaching point 1092" where, "while continuing to deposit the modeling material, extrusion head 20 steps over from perimeter path 1038a to begin forming perimeter path 1038b at point 1094." *Id.* at 12:17-25. Thus, the '239 patent describes creating a step-over arrangement between the start point and the stop point which creates an improved seam.



122. As the '239 patent describes, this method "effectively conceals the seam that is formed at the intersection of the starting and stop points." *Id.* at 3:4-5; *see also id.* at 5:8-10. This "intersection" occurs "where the outgoing and incoming roads meet" and "forms a seam for [the] layer." *Id.* at 6:33-37. The patent describes this point—the intersection between the outgoing and incoming roads—as the "step-over arrangement" in the disclosed invention. *See, e.g.*, *id.* at 12:15-28 ("… At this point, while continuing to deposit the modeling material, extrusion head 20 **steps over** from perimeter path 1038a to begin forming perimeter path 1038b at point 1094…." (emphasis added)), 12:46-56 ("In additional alternative embodiments, the **step-over arrangement** may be continued to form additional perimeter paths 1038…" (emphasis added)), 12:57-13:7 ("Additionally, the **step-over arrangement** also reduces the porosity of the 3D model 26 at seam 1164…" (emphasis added)); *see also id.* at 10:34-49 (stating that the "extrusion head 20 travels along contour tool path 640 in the direction of arrow 662 between

point 660 and stop point 654, overlapping the previously deposited modeling material" and the "overlapping arrangement shown in FIG. 10 further reduces porosity by effective overlapping the intersection at seam 664").

123. The patent also makes clear that the tool path creates the step-over arrangement. For example, the ’239 specification states that the extrusion head deposits modeling material along the contour tool path and while "continuing to deposit the modeling material, extrusion head 20 steps over from perimeter path 1038a to begin forming perimeter path 1038b" then continues "to move[] along contour tool path" until reaching a stop point. *Id.* at 12:15-28. Because, as I detailed above, the method disclosed in the ’239 patent is based in part on moving one or both of a start point and a stop point to the interior region of the layer, to form the step-over arrangement, the tool path must step from a perimeter to an interior or from an interior to a perimeter. *See also id.* at 12:54-56 (stating that "contour tool path 1040 may step over into the raster pattern to fill at least a portion of interior region 1050"). The patent further confirms my understanding when it discloses that "start point 1052 and stop point 1054 may be flipped such that start point 1052 is located within interior region 1050." *Id.* at 12:36-38. The patent goes on to state that a step-over arrangement can form an X-pattern seam by stepping from the exterior point 1052 to interior point 1054 after a step has been made from point 1094 to point 1092 in Figure 15. *Id.* at 12:38-42. Thus, the ’239 patent discloses that the step-over arrangement is the intersection at which the tool path steps from a perimeter to an interior region or from an interior region to a perimeter.

124. In addition, from my review of the ’239 prosecution history (attached as Exhibit F), it is clear that the inventors understood the step-over arrangement to be the intersection where the tool path steps from a perimeter to an interior or from an interior to a perimeter. In particular,

in the inventors' amendment and response to the patent examiner's non-final rejection, the inventors compared a patent issued to Jang with the claimed invention and stated that although Jang had a step-over arrangement, it did not have a step-over arrangement oriented at a non-right angle:

> As shown in FIG. 15 of the present application (reproduced below), the contour tool path 1040 of the given layer 1036 may include a start point 1052 and a stop point 1054 (present application, ¶ 70). The contour tool path 1040 also includes at least one step-over arrangement oriented at a non-right angle between the start point 1052 and the stop point 1054 (present application, ¶¶ 70 and 71). The non-right angle step over arrangement allows the deposited material to overlap at the step over, at a location that is offset inward from seam 1064, which eliminates the formation of bulges at seam 1064, and also reduces porosity at seam 1064 (present application, ¶ 71). . . . In comparison, the deposition pattern disclosed in ***Jang has a right-angle step over between layers, as shown in FIG. 7D of Jang (reproduced above). This right-angle step over requires the end point e1 of the outer perimeter L1 to be flush with the start point s1, and then turn inward to point a2 before starting the second perimeter L2. This doesn't allow the deposited material to overlap at the step over, such as is attainable with the non-right angle step over arrangement recited in claim 1.*** As such, claim 1 is not anticipated by Jang, and is allowable.

9/14/12 Amendment and Request for Reconsideration after Non-Final Rejection, at 7-8 (Exhibit F at STL00001019-20) (emphasis added).

125. Below I include Figure 15 from the '239 patent and Figure 7D from the Jang reference. *Id.* As they illustrate, the step-over arrangements are the intersection at which the tool path steps from a perimeter to an interior or from an interior to a perimeter, and are therefore consistent with my opinion that the step-over arrangement to be the intersection where the tool path steps from a perimeter to an interior or from an interior to a perimeter.

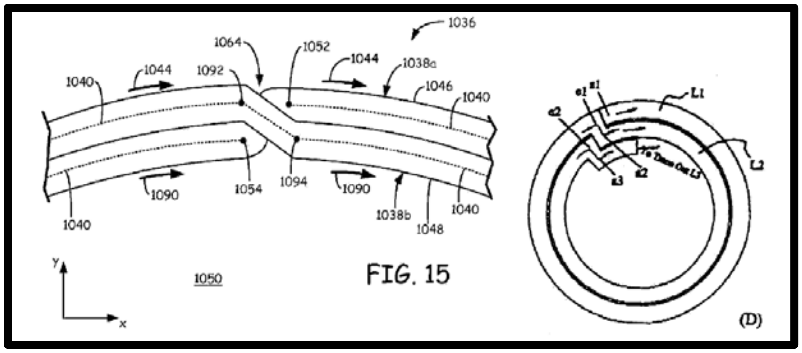


FIG. 15

126. As a result, after reading the disclosure in the ’239 patent and prosecution history, it is my opinion that a person of ordinary skill in the art would have understood the term “step-over arrangement” to mean the intersection at which the tool path steps from a perimeter to an interior or from an interior to a perimeter. Accordingly, in my opinion, a person of ordinary skill in the art in September 2009 would have understood “step-over arrangement” in the ’239 patent to mean “the intersection where the tool path steps from a perimeter to an interior or from an interior to a perimeter.”

6. “contour tool path”

127. In my opinion, a person of ordinary skill in the art in September of 2009 would have understood “contour tool path” to mean “an extrusion head path which defines a perimeter of a layer of a three-dimensional object.”

128. As I described in detail above, the ’239 patent discloses a method for printing a three-dimensional object that involves adjusting one or both of the start and stop points of a contour tool path to a location within the interior region of a layer. *See, e.g.*, ’239 patent at Abstract. In fact, the patent distinguishes and overcomes issues with the prior art extrusion-based three-dimensional printing systems in part on this basis. As I discussed in-depth above, the contour tool paths that are generated in the present invention have start points and stop points

that are adjusted "to one or more locations that are within an interior region of the layer defined by the respective contour tool path." *Id.* at 5:4-10.

129. The '239 patent also describes that the modeling material deposited along the disclosed contour tool path "is extruded through an extrusion tip carried by an extrusion head, and is deposited as a sequence of roads on a substrate." *Id.* at 1:17-19. For example, the patent discloses that "the modeling material is deposited along the contour tool path 40 in a clockwise direction, as represented by arrows 44, to form perimeter path 38." *Id.* at 6:1-3. In addition, the '239 specification explains that during "the build operation, extrusion head 20 follows the patterns of the tool paths for each layer, including the contour tool paths with the adjusted start and stop points." *Id.* at 8:32-35. Thus, the patent makes clear that the contour tool path is the path the extrusion head follows in depositing material. *See, e.g.*, *id.* at 9:6-15 (stating the "extrusion head 20 travels along contour tool path 240 between start point 252 and point 258" and then "travels along the contour tool path 240 between point 260 and stop point 254"), 10:8-18 (same), 10:23-28 (same).

130. The patent also makes clear that the contour tool path defines the perimeter of a layer of the three-dimensional object being printed. For example, the patent states that the desired model has "a perimeter based on a contour tool path" that defines an interior region of a layer of the three-dimensional model. *Id.* at Abstract. The patent also specifies that the "generation of the tool path(s) for a layer of 3D model 26 may initially involve generating one or more contour tool paths that define the perimeter(s) of 3D model 26 for the given layer." *Id.* at 5:1-4. Accordingly, it is my opinion that a person of ordinary skill in the art would have understood that in the context of this disclosure, contour tool path referred to a path that defined a perimeter of a layer of a three-dimensional object.

131. In my opinion, the ’239 patent prosecution history is consistent with my understanding of “contour tool path.” In particular, the inventors indicated in the prosecution history that the contour tool path defines a perimeter of a layer. 9/4/12 Amendment and Request for Reconsideration after Non-Final Rejection, at 7-8 (Exhibit F at STL00001022) (“a contour tool path (used to form a perimeter of a layer)”).

132. Thus, in my opinion, a person of ordinary skill in the art in September 2009 would have understood “contour tool path” to mean “an extrusion head path which defines a perimeter of a layer of a three-dimensional object.”

7. “reduces surface porosity”

133. It is my opinion that a person of ordinary skill in the art in September of 2009 would have understood “reduces surface porosity” to mean “reduces the transmission of gases and/or liquids through the seam.”

134. As I have detailed several times above, the prior art references and systems created start and stop points on a contour tool path that were collinear with the outer ring of the that paths. ’239 patent at 6:39-43. This path “was typically generated to match the geometry of the exterior perimeter of a 3D model layer,” such that the “stop point would end up being located next to the start point (e.g., at points 58 and 60).” *Id.* at 6:46-51. This start and stop point configuration created several issues, including bumps and gaps, as I also explained in detail above. *Id.* at 6:52-65. The patent describes that “a gap may be formed at the seam, which can increase the porosity of the 3D model. The increase porosity can allow gases and fluids to pass into or through the 3D model.” *Id.* at 6:59-65.

135. The patented invention solved the gap problem specifically with a method for concealing seams between start points and stop points by adjusting the location of the start point

and stop points such that the start point and/or stop point was located on the interior of the perimeter. *See, e.g.*, *id.* at 12:15-18 (discussing Figure 15); *see also id.* at 7:3-6 (discussing Figure 3). As a result of the adjusted start and stop points, the tool path steps from a perimeter to an interior or from an interior to a perimeter, thereby forming a seam that reduces the surface porosity of the object. *See, e.g.*, *id.* at 12:15-17. It is this reduced surface porosity that "reduc[es] or eliminat[es] the transmission of gases and/or liquids through seam." *Id.* at 7:35-40. The patent goes on to clarify that the step-over arrangement "also reduces the porosity of 3D model 26 at seam 1064, thereby reducing or eliminating the transmission of gases and/or liquids through seam 1064." *Id.* at 12:32-35.

136. The '239 patent prosecution history further confirms my understanding of "reduces surface porosity." For example, as I explained in detail above, the prosecution history makes clear that the patented invention reduces the porosity of the model and improves concealment of seams: "The contour tool path 1040 also includes at least one step-over arrangement oriented at a non-right angle between the start point 1052 and the stop point 1054 (present application, ¶¶ 70 and 71). The non-right angle step over arrangement allows the deposited material to overlap at the step over, at a location that is offset inward from seam 1064, which eliminates the formation of bulges at seam 1064, and also reduces porosity at seam 1064 (present application, ¶ 71)." 9/4/12 Amendment and Request for Reconsideration after Non-Final Rejection, at 7-8 (Exhibit F at STL00001019-20). In addition, the prosecution history shows that the inventors intended "reduces surface porosity" to mean reduces the transmission of gases and/or liquids through the seam. For instance, the inventors stated that "if not enough modeling material is deposited between points 58 and 60, a gap may be formed at the seam, which can increase the porosity of the 3D model. The increased porosity can allow gases and

fluids to pass into or through the 3D model, which may be undesirable for many functional purposes (e.g., for containing liquids) (present application, ¶ 45)." *Id.* at 9-10 (Exhibit F at STL00001021-22). The inventors further clarified that the "locations of start point 52 and stop point 54 also allow the deposited modeling material to form a seal at seam 64 that extends inward within interior region 50 (present application, ¶ 48). This ***reduces the porosity*** of 3D model 26 at seam 64, ***thereby reducing or eliminating the transmission of gases and/or liquids through seam*** 64 (present application, ¶ 48)." *Id.* (emphasis added).

137. In addition, dictionaries defined the term "porous" at the time of the '239 patent filing consistent with my understanding of "reduces surface porosity." For example, the Cambridge University Press dictionary defined "porous" as "allowing liquid or air to pass through" in 2008. Cambridge University Press, *Cambridge Dictionary of American English* 622 (2d ed. 2008) (attached as Exhibit G). Moreover, in 2005 the Oxford University Press defined "porous" for a rock "or other material" as "having minute spaces or hole through which liquid or air may pass." Oxford University Press, *The New Oxford American Dictionary* 1321 (2d ed. 2005) (attached as Exhibit H). Both of these dictionaries further confirm my understanding of "reduces surface porosity" and how the term is used in the context of the '239 patent.

138. For all of these reasons, it is my opinion that a person of ordinary skill in the art in September 2009 would have understood the phrase "reduces surface porosity" to mean "reduces the transmission of gases and/or liquids through the seam."

8. "raster path"

139. In my opinion, after reviewing the '239 patent and prosecution history, a person of ordinary skill in the art in September 2009 would have understood the term "raster path" to mean "back and forth path."

140. As I described above, the patent describes that both contour tool paths and raster tool paths are generated by the claimed system. The '239 patent in particular states that after generating the contour tool path, the system "may then generate one or more additional tool paths (e.g., raster paths) to fill in the interior region(s) defined by the perimeter(s), as necessary." '239 patent at 5:11-15; *see also id.* at 8:17-20 ("After the start and stop points are positioned in the interior region of the layer (e.g., within interior region 50 of layer 36), computer 12 may then generate additional tool paths (e.g., raster paths) to bulk fill the interior region (step 78)."). The specification further states that the interior region of the layer "may be filled with additional modeling material deposited along additionally generated tool paths (e.g., raster paths, not shown)." *Id.* at 6:12-16.

141. In my opinion, the patent specification also clarifies that the raster path is a back and forth path: "Upon reaching point 760, extrusion head 20 then turns and follow contour tool path 740 in the direction of arrow 762 and continues to deposit the modeling material in a back-and-forth raster pattern within interior region 750." *Id.* at 10:67-11:4. Likewise, the figures in the patent used to describe the raster paths, like my annotated Figure 11 below, further confirm that is the case.

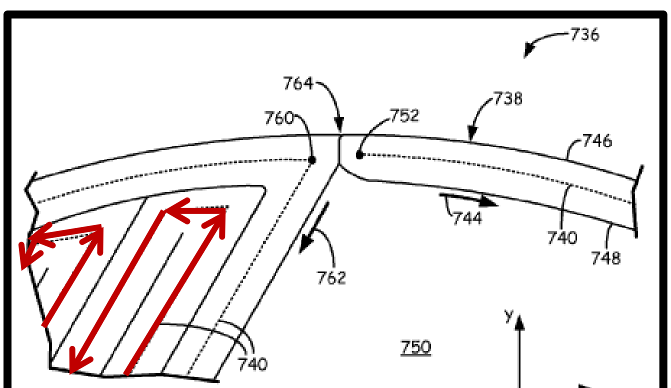


FIG. 11

142. Moreover, one of ordinary skill in the art would have understood that this back and forth path could have been performed in a number of different ways, including side-to-side, top-to-bottom, or bottom-to-top.

143. As a result, it is my opinion that a person of ordinary skill in the art in September 2009 would have understood the phrase "raster path" to mean "back and forth path."

9. "tool path"

144. In my opinion, after reviewing the '239 patent and prosecution history, a person of ordinary skill in the art in September 2009 would have understood the term "tool path" to mean "path of the extrusion head for a layer of a three-dimensional object."

145. As I explained in the Background of the Invention, the extrusion head moves along a tool path and deposits modeling material as it goes. *Id.* at 1:30-33. The extrusion head follows the tool path for each layer and accordingly deposits the modeling material (road(s)) on the tool path based on commands from the computer. Accordingly, the path the extrusion head follows as it deposits material defines the shape and dimensions of the three-dimensional model. Also as I described above, tool paths include different types of paths, including contour tool paths and raster paths, both of which were discussed above. For example, the patent describes that based on the generated contour tool paths, the printing system "may then generate one or more additional tool paths (e.g., raster paths) to fill the interior regions(s) defined by the perimeters(s), as necessary." *Id.* at 5:11-15.

146. The '239 patent also clarifies to a person of ordinary skill in the art that the tool path as used in the patent means the path of the extrusion head for a layer. For example, the patent states that "[d]uring the build operation, extrusion head 20 follows the patterns of the tool paths for each layer, including the contour tool paths." *Id.* at 8:32-35. The patent also

consistently describes that the contour tool path—a specific type of tool path—is one path the extrusion head follows in depositing material on a given layer. *See, e.g.*, *id.* at 9:6-15 (stating the "extrusion head 20 travels along contour tool path 240 between start point 252 and point 258" and then "travels along the contour tool path 240 between point 260 and stop point 254"), 10:8-18 (same), 10:23-28 (same). The '239 patent further specifies that the extrusion head follows and deposits modeling material along the raster paths—another specific type of tool path. *See, e.g.*, *id.* at 6:12-16 ("Interior region 50 is the region of layer 36 confined within perimeter path 38, and may be filled with additional modeling material deposited along additionally generated tool paths (e.g., raster paths, not shown)."). Thus, it is clear that the '239 patent refers to a tool path as the path of the extrusion head for a layer of a three-dimensional object that is being printed.

147. As a result, it is my opinion that a person of ordinary skill in the art in September 2009 would have understood that the '239 patent uses the term "tool path" to mean "path of the extrusion head for a layer of a three-dimensional object."

10. "perimeter of a layer"

148. In my opinion, the phrase "perimeter of a layer" should have its plain and ordinary meaning. It is a well understood term, which, in the context of claim 15 of the '239 patent, simply refers to the perimeter of a given layer in a three-dimensional model. Consequently, in my opinion the phrase "perimeter of a layer" is not in need of additional construction or clarification.

149. If the phrase must be construed, it is my opinion that, after reviewing the '239 patent and prosecution history, a person of ordinary skill in the art in September 2009 would

have understood "perimeter of a layer" to mean "road of modeling material that defines an interior region."

150. As I explained above, the extrusion head used to deposit the modeling material moves along tool paths while depositing a road of modeling material. *Id.* at 1:30-33. In particular, the '239 patent describes that the modeling material "is deposited as a sequence of roads on a substrate in an x-y plane." *Id.* at 1:16-19. The patent goes on to state that tool paths, including contour tool paths and raster paths are generated "for depositing roads of modeling material to form the 3D model." *Id.* at 1:30-33. Thus, in my opinion, it is clear that the "perimeter" identified in the '239 patent is a road of modeling material deposited by the extrusion head. *Id.* at 5:54-56 ("As shown in FIG. 2, layer 36 includes perimeter path 38, which is a road of a modeling material that is deposited by extrusion head 20 along contour tool path 40.").

151. The patent also consistently describes the creation of a perimeter of a layer according to the contour tool path. In particular, the '239 specification states that the invention as a whole relates to a three-dimensional printing system "having a perimeter based on a contour tool path that defines an interior region of a layer of the three-dimensional model." *Id.* at Abstract. In addition, in the Summary of the Invention, the patent specifies that the claimed invention "includes extruding a material in a pattern based on the tool paths to form a perimeter of the extruded material for one of the layers of the 3D model, where the perimeter has a start point and a stop point, and defines an interior region of the layer." *Id.* at 1:63-2:2. The patent repeatedly discusses that the perimeter defines the interior region of a layer. *See, e.g., id.* at 5:11-19 (stating that "one or more additional tool paths (e.g., raster paths) [can be used] to fill in the interior region(s) defined by the perimeter(s), as necessary"), 6:5-16 (stating that "[e]xterior

surface 46 is the outward-facing surface of perimeter path 38, which defines interior region 50" and that "[i]nterior region 50 is the region of layer 36 confined within perimeter path 38, and may be filled with additional modeling material deposited along additionally generated tool paths (e.g., raster paths, not shown)"). As a result, it is also my opinion that the '239 patent defines the term "perimeter of a layer" in part as defining the interior region of that layer.

152. Moreover, from my review of the '239 prosecution history, it is clear that the inventors understood the "perimeter of a layer" to be a road of modeling material that defines an interior region. In particular, in the inventors' amendment and response to the patent examiner's non-final rejection, the inventors stated that in comparison to their claimed invention, the prior art, "Jang does not disclose nor suggest the use of a single tool path to generate both the **perimeter** and an interior raster pattern. For example, the tool paths shown in FIGS. 7C and 8C of Jang (annotated versions reproduced below) do not **define an interior region** of the layer and would produce poor sea[m] concealment." 9/4/12 Amendment and Request for Reconsideration after Non-Final Rejection, at 11-12 (Exhibit F at STL00001023-24) (emphasis added). The specific figures from Jang that this statement was addressing, examples of which are provided below, lack a road of modeling material that defines an interior region.

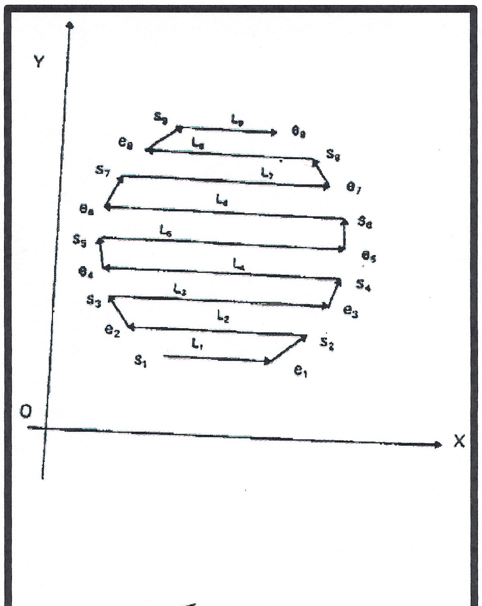


FIG 7(c)

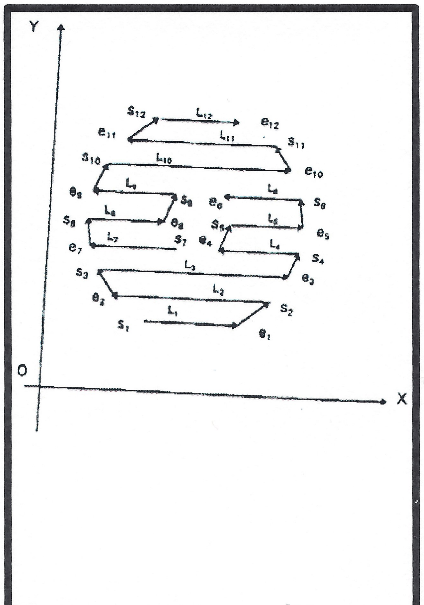


FIG. 8(c)

153. Based on these disclosures, it is my opinion that a person of ordinary skill in the art in September 2009 would have understood that the '239 patent uses the term "perimeter of a layer" to mean "road of modeling material that defines an interior region."

I declare under penalty of perjury under the laws of the United States that the foregoing statements are true and correct.

Executed on December 19, 2014 in Belle Mead, NJ.

Stephen C Danforth

Stephen C. Danforth, Ph.D.